



A University of Sussex PhD thesis

Available online via Sussex Research Online:

<http://sro.sussex.ac.uk/>

This thesis is protected by copyright which belongs to the author.

This thesis cannot be reproduced or quoted extensively from without first obtaining permission in writing from the Author

The content must not be changed in any way or sold commercially in any format or medium without the formal permission of the Author

When referring to this work, full bibliographic details including the author, title, awarding institution and date of the thesis must be given

Please visit Sussex Research Online for more information and further details

Emotional and social predictors of the trajectory of mathematical attainment across the transition from primary to secondary education.

Danielle Nicole Evans

Thesis submitted for the degree of Doctor of Philosophy

University of Sussex

August 2020

Abstract

This thesis examines the effects associated with the transition from primary to secondary education, focusing on maths attainment throughout childhood and adolescence. Existing research suggests that the transition to secondary education is especially problematic for the development of maths abilities and is associated with declines in maths-related affect. Moreover, the transition is linked to several changes within children's social, educational, and home environments, affecting their general wellbeing and overall development. Given the importance of maths attainment for a wide range of outcomes in adulthood, this thesis aims to add to the existing literature by identifying predictors of maths attainment trajectories and maths anxiety throughout this transitional period, with the purpose of helping to better inform educational interventions.

Following an introduction to the thesis, Chapter 2 is a review of international literature on the academic and psychological impacts associated with the transition to secondary education. This chapter discusses several negative outcomes associated with the transition and identifies risk and protecting factors for a successful transition. Using latent growth models of the Avon Longitudinal Study of Parents and Children (ALSPAC), Chapters 3-5 investigate emotional, cognitive, home, parental, and school-related predictors of maths attainment trajectories. The findings suggest internalising symptoms, working memory, parental education qualifications, school support, maths attitudes, parent-child relationships, and school/teacher affect predict maths attainment trajectories. In the final empirical chapter, maths anxiety in early adulthood is predicted from emotional symptoms and maths attainment over the transition using a linear model of the Twins Early Development Study (TEDS). Findings show that heightened emotional symptoms and decreased maths attainment over the transition predict increased maths anxiety in adulthood.

This thesis concludes with a discussion of the findings and proposes that transition strategies may benefit from focusing on improving student-teacher relationships, maths attitudes, and parental involvement in school activities across the transition.

Acknowledgements

Firstly, I would like to thank my supervisor Andy Field for his expert supervision and guidance over the past three years, and for making the work in this thesis possible. I am extremely grateful for your encouragement, patience, advice, and support, and have been incredibly fortunate to have had your extraordinary expertise throughout this endeavour. I have learnt so much during the past three years and will always treasure your humorous anecdotes which have made undertaking this PhD such a joyful experience. I would also like to thank Darya Gaysina for her supervision over the past three years. I am extremely grateful for all the support, advice, and feedback you have given me. I am so thankful and appreciative of your kind words of encouragement and your academic expertise over the past three years and am so privileged to have had you both as my supervisors. I am also very grateful for to the School of Psychology for the opportunity to pursue this PhD.

To my queens, Emma Syme and Rebecca Concannon, I am so incredibly grateful for your endless support, friendship, and love over the past seven years, and especially so during this PhD. I am so appreciative of you always listening to me go on about my research, for always checking up on me, believing in me, making me laugh, and guiding me through challenging times. You have always been so encouraging, motivating, and caring, and I could not have completed this without you both.

I am extremely grateful to my parents for constantly supporting me throughout my studies and for reminding me there is life outside of work, and to all my family for encouraging me to always do my best. I would also like to thank my friends who have always been incredibly supportive, especially, Ashleigh, Jack, Nik, Luca, and Dolapo, for your continuous encouragement, words of support, and pep talks when I needed them most. I would also like to express my gratitude to Claire Willis and James Ost for inspiring me to pursue this PhD, and for nurturing my desire for knowledge.

And finally, I am very thankful for the ongoing contribution of the families taking part in the TEDS and ALSPAC studies, the midwives and researchers involved in recruiting them, and the entire ALSPAC and TEDS teams, without whom, this project would not have been possible.

Declaration

This thesis has been written in a ‘papers style’ format whereby aside from minor editing, Chapters 2 to 6 are presented as they have been published (or under review), in peer reviewed journals. Author contributions for each chapter are given below. The first and final chapter provide an overview and discussion of the work in this thesis and therefore have not been submitted for publication.

Chapter 2 is published in *Frontiers in Psychology* as:

Evans, D., Borriello, G. A., & Field, A. P. (2018). A review of the academic and psychological impact of the transition to secondary education. *Frontiers in Psychology*, 9, 1482.

DE took the lead on the writing overall (notably the sections “Introduction”, “Discussion”, and the section “The Effects of the Transition to Secondary Education on Emotional Health”), did the initial planning, and coordinated the authors. GB took the lead on writing the section “The Effects of the Transition to Secondary Education on Academic Achievement” and had input on all drafts. AF supervised the project, commented on, and edited the first submission, and restructured and edited the revised version by introducing the conceptual framework in Figure 1.

Chapter 3 is published in *Royal Society Open Science* as:

Evans, D., Gaysina, D., & Field, A. P. (2020). Internalizing symptoms and working memory as predictors of mathematical attainment trajectories across the primary–secondary education transition. *Royal Society Open Science*, 7(5), 191433.

DE and AF conceived the study. DE analysed and interpreted the data and wrote the initial manuscript. AF supervised the project and reviewed the manuscript and data analysis process at all stages. AF commented on each draft of the manuscript and provided edits. DG reviewed the final manuscript and provided feedback and suggested minor revisions.

Chapter 4 is published in *Royal Society Open Science* as:

Evans, D., & Field, A. P. (2020). Predictors of mathematical attainment trajectories across the primary-to-secondary education transition: parental factors and the home environment. *Royal Society Open Science*, 7(7), 200422.

DE and AF conceived the study. DE conducted initial data processing and ran all statistical analyses with input and supervision from AF. DE wrote the manuscript and AF reviewed and revised the manuscript.

Chapter 5 is currently under review for publication as:

Evans, D., & Field, A. P. (2020). Maths attitudes, school affect, and teacher characteristics as predictors of maths attainment trajectories in primary and secondary education.

DE and AF conceived the study. DE conducted initial data processing and ran all statistical analyses. AF supervised the project and had input at all stages. DE wrote the manuscript and AF reviewed and revised the final draft of the manuscript.

Chapter 6 is published in *Royal Society Open Science* as:

Field, A. P., Evans, D., Bloniewski, T., & Kvas, Y. (2019). Predicting maths anxiety from mathematical achievement across the transition from primary to secondary education. *Royal Society open science*, 6(11), 191459.

AF, TB, and YK conceived the project. TB provided advice on measures and conducted initial data processing. AF ran all statistical analyses. AF, DE, and YK wrote the manuscript. Notably, DE wrote the “Introduction” and “Discussion” sections.

I hereby declare that this thesis and the work contained herein is the result of my own efforts except where explicitly stated. This thesis has not been and will not be, submitted in whole or in part to another University for the award of any other degree.

Danielle Evans

August 2020

Table of Contents

| | |
|---|------------|
| Abstract | 2 |
| Acknowledgements | 3 |
| Declaration | 4 |
| Chapter 1 | 8 |
| General Introduction | 8 |
| Overview of chapters | 15 |
| Summary | 19 |
| Chapter 2 | 20 |
| A review of the academic and psychological impact of the transition to secondary education | 20 |
| Introduction | 22 |
| The effects of the transition to secondary education on academic achievement | 27 |
| The effects of the transition to secondary education on emotional health | 38 |
| Discussion | 56 |
| Chapter 3 | 68 |
| Internalising symptoms and working memory as predictors of mathematical attainment trajectories across the primary-secondary education transition | 68 |
| Introduction | 70 |
| Method | 79 |
| Results | 87 |
| Discussion | 92 |
| Chapter 4 | 106 |
| Predictors of mathematical attainment trajectories across the primary-to-secondary education transition: parental factors and the home environment | 106 |
| Introduction | 108 |
| Method | 116 |
| Results | 128 |
| Discussion | 137 |

| | |
|---|------------|
| Chapter 5 | 148 |
| Maths attitudes, school affect, and teacher characteristics as predictors of maths attainment trajectories in primary and secondary education..... | 148 |
| Introduction | 150 |
| Method | 162 |
| Results | 178 |
| Discussion | 191 |
| Chapter 6 | 202 |
| Predicting maths anxiety from mathematical achievement across the transition from primary to secondary education..... | 202 |
| Introduction | 204 |
| Method | 213 |
| Results | 220 |
| Discussion | 225 |
| Chapter 7 | 230 |
| General discussion..... | 230 |
| References | 249 |
| Appendix | 322 |

Chapter 1

General Introduction

The importance of maths

The likelihood of hearing individuals say, ‘I can’t do maths’ is much greater than hearing ‘I can’t read or write’, and is typically met with much more acceptance and agreement from others. However, the consequences of poor maths attainment and abilities are arguably much more detrimental to society and individuals than poor literacy skills (Geary, 2011b). Low maths attainment is associated with poor career prospects including fewer employment opportunities, lower salaries, and lower rates of promotion, as well as a higher likelihood of mental and physical health problems, homelessness, and low socioeconomic status (Geary, 2011b; NRDC, 2013; Parsons & Bynner, 1997; Ritchie & Bates, 2013). Consequently, the costs associated with poor maths attainment in the UK is reported to be around £2.4 billion a year (Every Child a Chance Trust, 2009), though the importance of maths and numerical abilities is often overlooked by individuals (Geary, 2011b). By identifying factors associated with maths performance, we can develop and administer evidence-based interventions aiming to improve individuals’ maths attainment and consequently, their overall wellbeing. Therefore, this thesis broadly focuses on predictors of maths attainment and maths anxiety in childhood and adolescence using longitudinal data analysis methods.

The timing of this project is particularly pertinent. Recent statistics show that around half of working-age adults in the UK have the skills expected of primary-school children, 78% have numeracy skills below the average 16-year-old, and the UK’s

performance on international comparisons in maths is average compared to that of other nations - and is far below other countries that spend much less on education per child (National Numeracy, 2018; OECD, 2016a, 2016b), leading to what has been labelled as a ‘maths crisis’ (Carey et al., 2019) in the UK. It is evident that children’s low maths abilities when starting school are predictive of long-term attainment (Duncan et al., 2007), and so it is highly likely these deficits seen in adults begin in childhood. To address these difficulties with maths, we must focus on improving maths attainment and numerical skills in childhood and adolescence to prevent deficits worsening over time. By focusing on early life, we can implement interventions as early as possible which increases the effectiveness of the strategy.

In terms of the origins of maths skills in early childhood, it is evident that numeracy is moderately heritable (Kovas et al., 2013) with around two-thirds of the variance between children in middle-childhood explained by genetic differences. The goal of this thesis is not to separately examine the environmental and genetic factors associated with maths performance, but instead focus on different aspects of childhood and adolescence that are associated with maths attainment such as cognitive abilities, emotional functioning, environmental factors, and social experiences (all of which are likely to correlate and interact with genetic influences). Research within the field of maths education has typically focused on these domains throughout many different stages of development across the lifespan. Key investigations have focused on examining a broad range of topics such as the apparently innate ‘number sense’ present in young infants, severe emotional responses to maths (i.e. maths anxiety), the effects of maths-based stereotypes on performance, and the origins and implications of maths difficulties such as developmental dyscalculia (Dowker, Sarkar, & Looi, 2016; Geary,

1993; Gunderson, Ramirez, Levine, & Beilock, 2012; Izard, Sann, Spelke, & Streri, 2009). As evident in the breadth of research, maths as a subject area is very multifaceted, and encompasses a broad range of skills such as arithmetic, fractions, algebra, and geometry. However, the focus of this thesis is not children's performance on these individual aspects of maths that is often examined by research on maths cognition, but rather what factors influence children's formal grades in maths as measured by school-based assessments. The rationale for the focus on formal maths attainment is that it is these grades that facilitate access to further educational and career opportunities and are consequently especially important for long-term outcomes in adulthood.

Several variables associated with maths attainment (i.e. maths grades), have been identified thus far, including cognitive (i.e. working memory and inhibition), socio-emotional (e.g. maths anxiety and maths attitudes), and contextual (such as gender and socioeconomic status) factors (Bradley & Corwyn, 2002; Dowker, Cheriton, Horton, & Mark, 2019; Dowker et al., 2016; OECD, 2016a; St Clair-Thompson & Gathercole, 2006, 2006). However, to fully assess the long-term effects of predictors on maths attainment, and the possible intervention strategies that may help overcome difficulties, longitudinal methods must be utilised. Childhood and adolescence are periods of rapid growth and longitudinal methods provide greater insight into development, and the changes that occur during these periods. By employing longitudinal data analysis, we can evaluate which factors, characteristics, and experiences in childhood impact maths grades over the course of childhood and adolescence, and which variables have the strongest long-term effects on attainment.

Several studies have used longitudinal analyses to investigate maths attainment. The timescales used in these studies differ significantly; some use short time-intervals between measurement waves ranging from a few weeks to a few months, whilst others collect data across several years, or even decades. Some of these studies focus on the origins of maths difficulties (such as developmental dyscalculia; Nelson & Powell, 2018), while others investigating ‘typical’ maths attainment have focused predominantly on the importance of domain-general cognitive abilities (such as executive function, working memory, processing speed, and general intelligence) and the contribution of domain-specific abilities (such as nonsymbolic number line estimation) in early childhood (Alloway & Alloway, 2010; Bull, Espy, & Wiebe, 2008; Geary, 2011a; Sasanguie, Van den Bussche, & Reynvoet, 2012).

Very little research has considered factors unrelated to domain-specific, or domain-general abilities, especially focusing on long-term attainment as opposed to very short-term follow-ups. This paucity of longitudinal research spanning over several years means that there is a substantial gap in our knowledge of long-term predictors of maths attainment. Most of the aforementioned studies also focused on middle- to late-childhood, with very few studies examining children’s entire development, or later adolescence. This latter period of childhood is being increasingly recognised as a crucial timepoint in children’s development and involves one of the key events experienced by most children in early adolescence which is the transition from primary to secondary education. As will be discussed in the following section, this period represents several significant changes for adolescents, and is widely regarded as being particularly stressful. To date, very little research has focused on this period in development, and as will be argued throughout the entirety of this thesis, it is a critical timepoint for the

investigation of maths outcomes, and could be potentially a very effective period when implementing maths attainment interventions.

The transition from primary to secondary education

As stated above, adolescence marks a period of significant change and development. One key event occurring during early adolescence that is responsible for many of these changes is the transition from primary to secondary education. In the UK, this transition occurs at age 11, and is typically seen as a momentous occasion in which children begin to gain independence from their parents as they mature into young adults in the years following. The vast majority of children in the UK will change schools when moving between primary and secondary education, as will most children in other 'Western' countries (such as New Zealand, Australia, the US, and most European countries), with very few remaining in 'all-through' schools for the entirety of their education.

There are notable physical differences between primary and secondary education environments worth further discussion. Firstly, primary schools are usually much smaller than secondary schools; children are taught the entire curriculum by one teacher for each year group, and usually stay within the same classroom for all subjects throughout the school day. In secondary education, the curriculum is departmentalised where students have specialist teachers for different subjects, with lessons taking place in different classrooms. These changes place greater responsibility on children to ensure they are on-time to their classes and follow their timetable correctly, with the former often reported as being one of the major concerns of children transitioning (Akos & Galassi, 2004). The physical size difference between primary and secondary education

institutions is also a major concern of children, where they fear becoming lost in their new school environment. Where many smaller primary schools ‘feed’ into larger secondary schools, friendship groups are also often disrupted, with children renegotiating their social ties significantly across the move (Cantin & Boivin, 2004). These changes in the school environment are thought to affect children’s mental wellbeing, their social functioning, and their educational outcomes in a number of ways.

Existing research suggests that children experience emotional and social difficulties surrounding the transition with heightened stress and anxiety (Benner & Graham, 2009; Coelho & Romão, 2016), increased fear of victimisation following the move, and concerns about forming new friendships and relationships (Zeedyk et al., 2003). Many other researchers have reported declines in attainment, or interruptions in growth and progress across the transitional school-year, particularly within the domain of maths (Akos, Rose, & Orthner, 2015; Alspaugh, 1998; Serbin, Stack, & Kingdon, 2013). Galton, Gray, and Ruddock (1999) found that around 34% of children fail to show any progression in maths during the transitional year. Negative affect towards maths (e.g. maths attitudes, involvement, interest, and anxiety) has been found to increase across the transition also (Barth et al., 2011; Deieso & Fraser, 2019; Wilkins & Ma, 2003). Together these findings suggest the transition event is a potentially critical timepoint for maths outcomes, which is the idea this thesis aims to examine in greater depth.

It is apparent that maths attainment is negatively affected by the move to secondary education, however, the absence of research makes it difficult to draw definitive conclusions regarding the long-term effects. Additional research is vital to further understand the impacts of the transition, and the associated effects on maths

attainment to better inform educational policy, and intervention strategies for low maths attainment and the transition to secondary education. Of the few studies that have investigated maths-outcomes, there is an absence of longitudinal studies spanning over several years - most of the longitudinal research conducted has been over short-term follow-ups meaning that we can only infer the short-term effects.

As noted above, utilising longitudinal research would facilitate a greater understanding of the factors affecting attainment long-term and would help identify focal areas for the most effective methods for improving maths education, consequently enabling children to make more successful transitions to secondary education. Therefore, based on the aforementioned research, and the gaps in the existing literature, the aim of this thesis is to investigate the associations between experiences and attributes in childhood, and maths anxiety and maths attainment using longitudinal data analysis of two UK birth cohorts; the Avon Longitudinal Study of Parents and Children (ALSPAC; Boyd et al., 2013) and the Twins Early Development Study (TEDS; Haworth, Davis, & Plomin, 2013). The timepoint focused on specifically is the transitional period from primary to secondary education in early adolescence. As highlighted briefly above, and discussed in greater detail in the following chapter, this period in adolescence is associated with various changes in children's social, educational, and home environments, and additionally coincides with other biological changes (i.e. puberty), making it a key period in development for further investigation.

To better understand the impacts of the move to secondary education, and what influences maths attainment across the transition, this thesis broadly investigates cognitive abilities, affective factors, and aspects of children's home and school

environments in childhood and early adolescence. Specifically, the key research questions examined in this thesis are:

- What is the impact of the primary to secondary education transition on academic and psychological outcomes?
- How does working memory capacity and internalising symptoms contribute to maths attainment trajectories?
- In what ways do parents and the home environment affect maths attainment trajectories?
- Which school-related factors are the most important for maths attainment trajectories in primary and secondary education?
- Are emotional difficulties and maths under-attainment around the transition to secondary education key factors in the development of maths anxiety?

Overview of chapters

The following five chapters of this thesis address each of the research questions above, with a detailed literature review present in the introduction of each chapter, and so here, I will summarise each chapter in turn and overview the research presented.

Chapter 2 aims to assess the impact of the transition from primary to secondary education. This narrative review focuses on integrating international literature investigating the psychological and academic impacts associated with the transition to secondary education for schoolchildren transitioning from primary to secondary schools in the UK, and the equivalent elsewhere (i.e. the middle-school transition in the US). This chapter focuses on academic and psychological impacts as two of the most affected outcomes across the transition and also identifies risk and protecting factors that increase or decrease the likelihood of negative outcomes following the transition. I discuss some of the potential opportunities for intervention strategies and highlight the gaps and inconsistencies in the existing literature.

In Chapter 3, I begin my three-phased investigation into the predictors of maths attainment trajectories using latent growth models of secondary data from ALSPAC by examining whether greater working memory capacity and fewer internalising symptoms are associated with increased maths attainment trajectories (i.e. attainment at age 11, and the rate of change over time). These hypotheses are based upon the processing efficiency theory (Eysenck & Calvo, 1992) which states that when working memory resources are consumed by high levels of anxiety, performance on tasks is negatively affected. Existing research shows support for both working memory and internalising symptoms as predictors of maths attainment (Dobbs, Doctoroff, Fisher, & Arnold, 2006; Raghubar, Barnes, & Hecht, 2010), however, little research has examined these associations longitudinally, and also whether internalising symptoms explain the association between working memory capacity and maths attainment (as opposed to the association between anxiety and working memory as proposed by the processing efficiency theory; Eysenck & Calvo, 1992; Owens, Stevenson, Norgate, & Hadwin, 2008). The key findings presented in this chapter show that working memory and internalising symptoms are independently associated with maths attainment trajectories, meaning that working memory capacity does not moderate the effects of internalising symptoms on maths attainment. These findings contrast prior studies investigating anxiety and working memory and imply that the processing efficiency theory is only applicable to anxiety symptoms.

Chapter 4 follows on from the analyses in Chapter 3 by focusing on predictors of maths attainment trajectories relating to parental factors and parent-child interactions within the home-environment. Parents are one of the most important support systems children have, especially during early adolescence, and this study aims to better

understand how parental factors influence long-term attainment. This study focuses on a wide range of variables including early home teaching, parental mental health, parent–child home interactions, parent–child relationships, school involvement, parental education qualifications and child gendered play, and how these factors affect attainment trajectories across the secondary education transition. I propose that children with more positive home- and parental factors have higher maths attainment. The results demonstrate that parental involvement in school prior to the transition, parental education qualifications, and harmonious parent-child relationships are associated with maths attainment trajectories, implying that parents are particularly important around the time of the transition and influence long-term effects.

The final phase of the ALSPAC analyses, presented in Chapter 5, investigates school- and maths-related variables and their association with maths attainment trajectories. I present two latent growth models examining variables relating to the school environment and attitudes towards maths, measured in primary and secondary education separately. In the first model (i.e. factors measured in primary education), I investigate the links between maths attainment and school affect, student-teacher relationships, maths attitudes, teacher affect, teacher mental health, and teacher self-esteem. In the second model, (i.e. factors measured in secondary education), I assess the associations between maths attainment and school belonging, student-teacher relationships, negative school emotion, maths attitudes, positive teaching in maths, and maths-teacher fairness. I hypothesise that in both models, more positive affect towards school, teachers, and maths, is associated with increased attainment, and that children's attainment is lower where their teachers have low self-esteem, negative affect towards teaching, and poor mental wellbeing. Here I draw upon the stage-environment fit theory

(Eccles et al., 1993), as a theoretical explanation of why primary and secondary education environments may differ in their effects on attainment. The stage-environment fit theory proposes that there is often a mismatch between adolescents' needs and their environment during this period in early adolescence, and consequently argues that adolescents have better outcomes when these needs are appropriately met. It is thought that the secondary education environment is less able to cater to these changing needs (Eccles et al., 1993), which I aim to assess further by investigating factors in primary and secondary education separately. The findings show that in primary education, the only factor that is significantly associated with maths attainment trajectories is maths attitudes. Whereas, in secondary education, maths attitudes, school belonging, student-teacher relationships, and teacher-fairness are associated with maths attainment trajectories. These findings suggest that the secondary education environment is especially influential for attainment.

Throughout Chapters 3-5, I aim to improve our understanding of the predictors of maths attainment across the transition from primary to secondary education. In Chapter 6, I will use some of this knowledge in examining variables around the transition to secondary education as predictors of maths anxiety in adulthood. In this chapter, using a linear model of secondary data from TEDS, I assess whether trajectories of emotional symptoms and maths attainment across the transitional period, are linked to maths anxiety in early adulthood. I hypothesise that increasing trajectories of emotional symptoms and decreasing trajectories of attainment will be associated with increased maths anxiety. In this study, the results show that trajectories of emotional symptoms and maths attainment during the transitional period are linked to maths anxiety in early adulthood. The findings imply that children experiencing poor

transitions (in terms of emotional and academic functioning) are at-risk of long-term negative outcomes.

Summary

Throughout this thesis, I aim to further uncover predictors of maths attainment trajectories across the challenging transition to secondary education. This work is needed to better inform education practices and policies regarding maths attainment, and to develop effective transition strategies. The research presented throughout this thesis is in the ‘papers style’ format as four of the empirical chapters have been fully published, with one currently under peer review. A *chapter prologue* is included at the beginning of all the empirical chapters to highlight the links between the analyses, and how the investigations build on each other.

As will be discussed further in the following chapters, the main findings of this thesis indicate that the transition to secondary education is a particularly stressful event and a number of factors influence children’s experiences and how well they adapt to secondary education. When looking specifically at maths outcomes, it is clear that a number of cognitive, emotional, parental, and school-related factors influence maths attainment and anxiety throughout this period, which has important implications for educational policies.

It is hoped that the work in this thesis builds upon our current understanding of the factors influencing maths attainment during childhood and adolescence, whilst providing evidence-based suggestions for intervention strategies, with the aim of helping every child succeed and thrive in school.

Chapter 2

A review of the academic and psychological impact of the transition to secondary education

Chapter Prologue

This chapter lays the foundations for the remainder of the thesis by assessing the effects associated with the transition from primary to secondary education. In this chapter, I integrate and discuss the existing research examining the psychological and academic effects associated with the transition and evaluate the influence of additional factors that might increase or decrease the likelihood of children experiencing poor transitions. This review of the literature builds on existing knowledge by assimilating the findings into a conceptual framework, and by identifying gaps in the literature worth further investigation.

Abstract

The transition from primary to secondary education is one of the most stressful events in a young person's life (Zeedyk et al., 2003) and can have a negative impact on psychological well-being and academic achievement. One explanation for these negative impacts is that the transition coincides with early adolescence, a period during which certain psychological disorders (i.e. anxiety disorders) become more salient (Kessler et al., 2005) and marked social, biological, and psychological development occurs (Anderson, Jacobs, Schramm, & Splittgerber, 2000). This review evaluates the existing literature on the psychological and academic impacts of the transition to secondary education on young adolescents. We examine the factors that plausibly increase or mitigate the risk of developing mental health issues and/or a decline in academic performance during the transition to secondary education. We also review the interplay between psychological health and academic achievement across and beyond the transition. We conclude with a summary of what schools and parents can learn from these findings to support children in a successful transition into secondary education.

Introduction

The transition from primary to secondary education is a normative event for most children around the world, which typically occurs when children are early adolescents (mostly between the ages of 10-14). Although most students change school at some point during their education, systems around the world vary significantly. For example, in England, children transition in Year 6 at age 11, whereas in the United States (US), the age and grade of transition differs per school and per state, with children transitioning between the ages of 10 and 14 to a middle or high school (5th and 8th grade, respectively). While it is the norm to transition, it is possible that children may also attend schools in which they complete their education in one institution, though these are uncommon in the United Kingdom. To avoid switching between locale-specific terms, for the entirety of this review, primary education refers to schooling before children transition to a middle school, high-school (United Kingdom), secondary school, or a gymnasium around the ages of 10-14, while secondary education refers to schooling after this transition.

Around two in five students fail to reach their expected progress following the transition to secondary education (Galton et al., 1999), with around 40% of students making no progress in English and reading (42 and 38%, respectively) and 34% making no progress in maths from Year 6 (age 10-11) to Year 7 (age 11-12) (Galton et al., 1999). In the United Kingdom, Ofsted (2002) concluded there was limited preparation available for the differences in teaching and learning children face after the transition.

The transition to secondary education has received increased interest from researchers in recent years, with many researchers regarding the change as one of the

most stressful events young adolescents will experience (Chung, Elias, & Schneider, 1998; Coelho & Romão, 2016). Children report additional concerns during this time, including fear of bullies, being lost, peer relationship worries, and anxiety over coping with an increased workload (Zeedyk et al., 2003). Additionally, the transition to secondary education can directly impact educational attainment, with a reported interruption in students' academic growth during the transition year (Akos et al., 2015).

Figure 1 shows an attempt to organize the various constructs that, based on research, contribute to a successful transition to secondary education. The first consideration is what is deemed a “successful” transition. Although the adjustment to secondary education can be measured in various ways, most researchers regard it to encompass social, academic, and emotional adaptation (Duchesne, Ratelle, & Roy, 2012). Hall and DiPerna (2017) particularly note the importance of relationships with peers, developing academic abilities, and a stable state of mental health as vital components of adjusting to secondary education. These components are not independent. Where there are declines in emotional well-being, there are also declines in peer relationship quality, and academic performance, though causality has yet to be established (e.g. Mundy et al., 2017; Rahman et al., 2018; Reijntjes, Kamphuis, Prinzie, & Telch, 2010; Woodward & Fergusson, 2000). Although many students adapt with relatively few issues, others find the transition impacts one, two, or all of these domains. It has been argued that children who express more worries prior to the transition are less likely to be well-adjusted in all three of these areas (Duchesne et al., 2012)

In terms of what predicts a successful transition, Figure 1 organizes the key constructs into higher-order categories of contextual, environment-, and individual-level constructs. Contextual constructs are variables that could plausibly moderate any of the

relationships between the environmental-level constructs, individual-level constructs and a successful transition. The contextual constructs could all plausibly have a direct impact on whether the transition is successful too. They have in common that they are either fixed during transition (e.g. pre-transition academic attainment/emotional health, biological sex, whether we consider the model for a specific subject area such as maths), likely not to change (e.g. SES), or the effect of change is likely to be fixed at the group level (for example, we might consider the effects of puberty to be somewhat similar for all boys). The environment- and individual-level constructs are ones that are highly likely to change heterogeneously during transition to secondary education (for example, there is likely to be considerable variability in how dramatically the school environment changes for different children). They differ, self-evidently, in whether they relate to the child's environment or his/her internal schema.

Within these categories, we have pulled together related measures from the literature into superordinate constructs. For example, researchers have looked at class size, teacher expectations, and academic goal orientation as predictors of a successful transition, all of which can logically be grouped as part of the school environment. Similarly, a child's set of beliefs about their social environment and her/his emotional responses to them (which we have labeled social schema) encompasses peer relations, teacher relations, affect to school (or belongingness), and social support more generally. The constructs identified are not exhaustive or definitive, they are merely a convenient way to organize the existing literature for the purpose of this review.

Within the environment-level constructs, most of the literature relates to changes in the child's school or home environment. The overall school environment typically changes during the transition to secondary education. Children often move from a

smaller, personal primary school where they are taught by a single teacher in, primarily, a single classroom, to a larger, more complex, impersonal secondary school where they attend lessons in different locations with different teachers, often with larger class sizes. Secondary school buildings tend to be larger, and individuals are often required to travel further afield, often on public transport.

Within the individual-level constructs, the literature focuses on the belief systems in the child about their social position, their learning, and their academic self-concept. For example, Cantin and Boivin (2004) report a decrease in friendship network size following the transition, meaning children have fewer friends post-transition. Similarly, Martínez, Aricak, Graves, Peters-Myszak, and Nellis (2011) note a decline in both general social support and the support given by teachers at this time. These findings are represented by social schema in Figure 1.

The constructs identified are, of course, not independent. The environment-level constructs could plausibly have a direct effect on a successful school transition, but also an indirect effect by influencing any one of the individual-level constructs. For example, the classroom goal structure alters post-transition with higher importance placed on performance goals, where the focus is on demonstrating ability relative to others, as opposed to mastery goals, where the focus is on increasing competence relative to self-set standards (Madjar et al., 2018a). This shift in goals in turn negatively impacts social schema such as school belongingness/engagement (Madjar & Chohat, 2017). Similarly, decreased emotional support in the classroom has been reported following the transition (Shell, Gazelle, & Faldowski, 2014), which is likely to impact social schema. The individual-level constructs are also likely to influence each other: social and learning schemas are both likely to influence academic self-concept and plausibly each other.

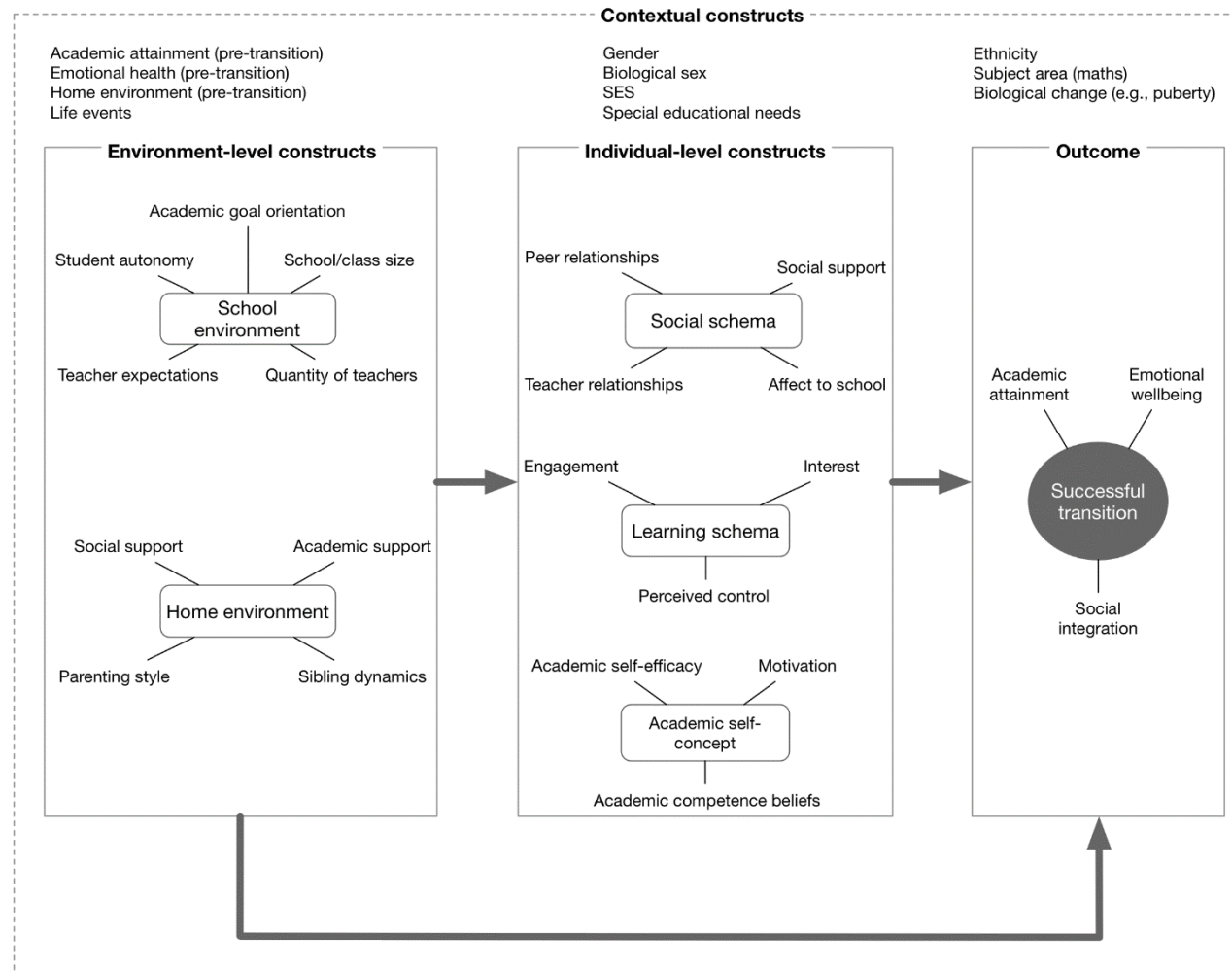


Figure 1. Summary of the key constructs influencing a successful transition to secondary education.

We aim to evaluate the academic and psychological impact of the secondary education transition, while examining risk and protective factors that may amplify or lessen these effects. Based on Hall and DiPerna (2017) definition, we primarily review the evidence concerning emotional well-being and academic performance. Because so little is known about the causal relationships between the identified constructs, we believe it is misleading (not to mention messy) to make individual connections in Figure 1 between the various constructs that might imply causality. Instead, this review will highlight the relationships between the constructs in the Figure 1 that have been observed, but there may be other connections that, as yet, have not been explored empirically.

The effects of the transition to secondary education on academic achievement

The first indicator of a successful transition to secondary education is academic achievement (Figure 1). Academic achievement is essential for individual well-being across the lifespan (Fiscella & Kitzman, 2009; Gottfredson, 2004). The primary-to-secondary transition is a critical period of development in which many children are particularly vulnerable to lower levels of academic achievement. Low academic achievement during early adolescence is linked with various negative consequences, including early pregnancy and higher delinquency rates (Freudenberg & Ruglis, 2007; Henry, Knight, & Thornberry, 2012; Kasen, Cohen, & Brook, 1998). Moreover, low achievement during this period tends to be succeeded by school dropout and low occupational achievement and income across the lifespan (Day & Newburger, 2002). In this section, we summarize research that has examined the impacts of the primary-to-secondary transition on academic-related outcomes in early adolescence.

A number of United States studies indicate that the transition from primary to secondary education has a negative impact on student grade point averages (GPA) and academic achievement (Alspaugh & Harting, 1995; Dotterer, McHale, & Crouter, 2009; Felner, Primavera, & Cauce, 1981; Gutman & Midgley, 2000; Seidman, Allen, Aber, Mitchell, & Feinman, 1994; Simmons, Black, & Zhou, 1991). Illustratively, United States students who moved from a primary to a secondary school experienced a decline in grades following the transition, unlike students who were in the same grade but had not transitioned to secondary education (Felner et al., 1981). Alspaugh (1998) also found that U.S. children experience lower academic achievement after transitioning from primary school to secondary school. Moreover, children who transitioned into secondary education where peers attended a variety of primary schools experienced lower levels of achievement than children who transitioned into secondary education with peers who attended the same primary school. Results from achievement at the high school level indicated that U.S. children who transitioned multiple times, from primary to secondary school and from secondary school to high school, experienced higher declines in achievement than those who had fewer school transitions. Alspaugh's (1998) work is in line with other evidence (Rice, 2001) suggesting that the transition from primary to secondary education can have long-term negative consequences on academic outcomes.

Environment-level constructs

With respect to the environment-level constructs in Figure 1, developmental psychologists have attempted to understand why and how the transition to secondary education can negatively affect academic achievement. The stage-environment fit model

(Eccles et al., 1993) suggests that a mismatch between children's developmental needs at the time of the transition and the social context of secondary schools contributes to a decline in academic outcomes following the transition.

Several aspects of the secondary education school environment that differ from primary education may have a particular effect on academic achievement following the transition; these include new academic environments (e.g. new, larger schools and classrooms) and different structural demands (e.g. switching classrooms, teachers, and classroom materials for each subject throughout the day). Children must also forge new student-teacher relationships and adjust to changes in teacher expectations and declines in student autonomy.

Although teachers have more control over secondary education classrooms, academic standards tend to be higher in secondary education than in primary, and require more intrinsic motivation from adolescents (Harter, Whitesell, & Kowalski, 1992). Compared to primary education, secondary education classes place an increased emphasis on grades and teachers' academic expectations of students tend to be higher (Eccles & Midgley, 1989; Wigfield, Eccles, Mac Iver, Reuman, & Midgley, 1991). Moreover, children may perceive classroom goals differently in primary and secondary education. Cross-sectional work indicates that in primary education settings, students report being more task oriented, or engaged in academic work for the sake of learning, whereas in secondary education settings children report being more performance oriented, or engaged in academic work for the sake of demonstrating ability (Anderman & Midgley, 1997). A longitudinal study found that following a transition from primary to secondary education, children perceived classroom climates to focus more on

competence and less on learning (Anderman & Midgley, 1997). These changes subsequently influence individual-level constructs such as adolescents' academic self-concept, interest and engagement (learning schema), and affect toward school (social schema), as discussed in the following sections.

Individual-level constructs

Academic self-concept.

Academic self-concept, or self-perceptions regarding academic topics and learning, has various components, including a cognitive component specific to academic competence and an affective-motivational component (Arens et al., 2013a; Marsh, Craven, & Debus, 1991). Studies indicate that academic self-concept decreases between the end of primary and the beginning of secondary education (Arens et al., 2013a; Wigfield et al., 1991). For example, Coelho, Marchante, and Jimerson (2017) found decreases in students' academic self-concept from their last year in primary education to the end of their first year in secondary education, along with lower levels of self-esteem. Although this sample included Portuguese children who transitioned to secondary education 2 years earlier than students in the United Kingdom or the U.S. typically do, these findings are consistent with studies examining children who transition to secondary education at a later age (Wigfield et al., 1991). In addition, Seidman et al. (1994) found that students' academic self-perceptions declined even after adjusting for student age, grade level, and ability level. Together, these findings provide evidence that the transition process itself (i.e. the environment) as well as individual factors (e.g. developmental changes), likely play a role in changing children's academic self-concept.

However, there is inconsistency in the literature with not all studies finding a decline in perceived academic competence after the transition to secondary education. For example, Harter et al. (1992) found no significant differences between children's perceptions of scholastic competence following the transition to secondary education compared to children who did not transition. There are also studies demonstrating increases, not decreases, in academic self-efficacy (Midgley, Anderman, & Hicks, 1995; Zimmerman & Martinez-Pons, 1990). The variance in observed changes in perceptions of academic competence across the transition period must be explained by other factors, including how much children value a particular academic domain and their interest in it. Moreover, we might expect changes in academic self-concept to differ by discipline. For example, Wigfield et al. (1991) found significant declines in children's perceived competence in English following the transition to secondary education, but only marginal declines in mathematics. In the Section "Learning Schema," we discuss student attitudes and interest in a select few academic domains.

Learning schema. Students tend to hold more negative attitudes toward certain academic domains including mathematics and science, compared to others, and to academic achievement, more broadly (Eccles, Midgley, & Alder, 1984). Student self-perceptions about their own abilities in and attitudes toward maths and science tend to decrease as children progress in school, and especially during the transition to secondary education (Eccles et al., 1984; Midgley et al., 1989a). For example, a cross-sectional study by Barth et al. (2011) found that children's attitudes toward and self-efficacy in mathematics and science declined during the transition. Similarly, student interest in mathematics and science were lower after, rather than prior to, the transition to secondary education. Furthermore, Australian students reported less involvement in

the classroom and declining enjoyment and attitudes toward maths following the transition relative to those yet to make the move over to secondary education (Deieso & Fraser, 2019).

Differences in learning experiences surrounding science and mathematics before and after the primary-to-secondary transition may also influence changes in students' academic attitudes and interests. Prior to the transition, for example, students do not have a choice in the type of science or mathematics courses in which they enroll and instruction in these arenas is standardized across students. Following the transition to secondary education, students have more agency in the number and type of mathematics and science courses they choose. Moreover, student ability in these domains becomes more salient, and students tend to get grouped into courses with students who have similar abilities to their own. Moreover, as children progress through school, teacher support decreases. Barth et al. (2011) investigated whether the role of teaching effectiveness and student perceptions of positive teaching strategies (i.e. teacher support, engaging instruction) contributed to decreases in student interest and attitudes toward maths and science. Findings indicated that effective teaching and student perceptions of positive teaching strategies strongly predicted changes in student interest and self-efficacy in mathematics and science, particularly during the transition to secondary education. Thus, one way that negative attitudes toward and low self-efficacy and interest in mathematics and science across the transition period may be counteracted is via teacher support.

The transition to secondary education also affects engagement and perceived control in learning. A study by Rudolph, Lambert, Clark, and Kurlakowsky (2001)

examined whether student perceptions of control over their academic outcomes as well as student investments in academic success influenced their ability to successfully transition from primary to secondary education. The researchers expected to find that high perceptions of control and personal investment in academic success would encourage academic engagement and ultimately, academic achievement. Conversely, they expected that low levels of control and investment would promote academic disengagement and hinder academic achievement. Results indicated that, compared to students who did not transition from primary to secondary education, students who experienced a transition and reported lower levels of perceptions of control and personal investment in school also reported higher levels of stress and depressive symptoms. The authors suggest that students with lower levels of perceived control over and personal investment in academic pursuits are more likely to become disengaged from school and to find it easier to feel overwhelmed or particularly sensitive to any school-related issues.

Social schema. Student feelings of “belongingness” at school and how much they enjoy school may also be impacted by school transitions and affect child achievement. Because intervention research suggests that a positive school climate can benefit children’s mental health and academic outcomes, several studies have investigated whether changes in the school climate between primary and secondary education contributes to declines in academic outcomes post-transition (Battistich, Schaps, & Wilson, 2004). Illustratively, Riglin, Frederickson, Shelton, and Rice (2013) examined bidirectional associations between young adolescents’ ($M_{\text{age}} = 11.78$ years) affect toward school and their academic achievement using a prospective, longitudinal design. They found reciprocal associations between school liking and academic

achievement at the beginning and end of the first year of secondary education.

However, after controlling for conduct problems, degree of liking school predicted later academic achievement, but early achievement no longer predicted later school liking.

These findings support the notion that affect toward school and a sense of belonging to school are linked with academic achievement (McLaughlin & Clarke, 2010; Resnick et al., 1997; Roeser, Eccles, & Sameroff, 2000). However, some studies have not found evidence to suggest that children's perceptions of the school climate differ prior to and following the school transition (Crockett, Petersen, Graber, Schulenberg, & Ebata, 1989; Fenzel & Blyth, 1986; Harter et al., 1992; Hirsch & Rapkin, 1987; Thornburg & Glider, 1984), and other studies report positive child perceptions of the school climate post-transition (Berndt & Mekos, 1995; Nottelmann, 1987; Schulenberg, Asp, & Petersen, 1984). These findings indicate a need for more research to investigate links between the school climate before and after the primary-to-secondary education transition and its effects on academic achievement in early adolescence and beyond.

Interplay between individual-level constructs.

It is important to understand the interplay between academic achievement, social schema, learning schema, and academic self-concept because doing so provides clear target areas to help children to maintain academic achievement across the transition to secondary education. The way that students cope with changes in academic achievement after the transition may have long-term consequences for future achievement. If initial decreases in grades or achievement post-transition leads some students to alter their academic self-concept, they may become more disengaged with school and have more negative feelings toward school, or increased feelings of disconnectedness. In turn, teachers may interact with students in a more negative way and these effects can snowball and lead to future

decreases in student achievement or engagement (Eccles et al., 1993; Fenzel, 2000).

Conversely, it is also possible that for students with more resources and personal investments in learning, initial declines in grades following the transition may motivate them to become more engaged at school and work harder to bring up their grades. Thus, the ability of a young adolescent to continue doing well academically following a school transition is likely to depend on both the interplay between the individual-level factors and the environment-level factors that influence them.

Contextual variables

So far, we have reviewed the environment- and individual-level factors affecting the transition from primary to secondary education. However, a range of contextual variables have been identified as predictors of academic performance across the transition to secondary education. For example, pubertal status has been linked to changes in academic self-concept and self-representation, both of which are important for academic achievement (Schaffhuser, Allemand, & Schwarz, 2017). This section summarizes what we know about some of the contextual variables identified in Figure 1.

Gender. Few studies examining the school transition have reported consistent evidence of gender differences impacting future academic outcomes (Harter et al., 1992; Seidman et al., 1994; Wigfield et al., 1991). For example, Seidman et al. (1994) found that children's grades declined following the transition regardless of gender. Studies examining motivation, attitudes toward, and self-concepts in specific academic domains have found that boys tend to have more positive attitudes toward and higher self-concepts in maths than girls, whereas girls tend to have more positive

attitudes toward and higher self-concept in English than boys (Eccles et al., 1984; Marsh, 1989). However, research findings regarding effects of gender on self-concepts and attitudes toward academic achievement, and how these characteristics vary by gender across the transition period, are inconsistent.

Cognitive and emotional traits. Studies have reported a number of cognitive or emotional traits that influenced findings regarding the school transition and academic outcomes (Petrides, Frederickson, & Furnham, 2004). For example, a longitudinal study examined the development of self-control during early adolescence, as children transitioned from primary to secondary education, and found that students with higher levels of self-control adjusted better following a school transition, receiving higher grades in English, maths, and science courses (Ng-Knight et al., 2016).

Several studies suggest that how well children adapt to a new school environment and perform academically may depend on ability level in academic domains prior to a transition. For example, Wigfield et al. (1991) examined students' academic self-concept in mathematics prior to and following a secondary education transition and found that children's mathematics self-concept following a school transition varied by level of mathematics ability. For students with high mathematics ability, mathematics self-concepts declined over time following the transition, while students with low mathematics ability experienced slight increases in their mathematics self-concepts following the transition. Other studies have also reported that academic ability level can help explain effects of school transitions on young adolescents' academic-related outcomes (Anderman, 1998; Midgley et al., 1989a, 1989b). For example, in a longitudinal study (Midgley et al., 1989a) teacher influences on student

perceptions of the importance of mathematics before and after the secondary transition depended on student mathematics achievement. Results indicated that, compared to high achieving students, low achieving students had steeper declines in perceptions of mathematics importance if they switched from more supportive teachers before the transition to less supportive teachers following the transition.

With respect to emotional traits, Qualter, Whiteley, Hutchinson, and Pope (2007) found that compared to students with below average emotional intelligence, those with average or higher levels of emotional intelligence received better grades in school, and had fewer teacher concerns regarding effort following the transition to secondary education (age 11-12).

SES and ethnicity. Because youth of lower socioeconomic status (SES) tend to have lower academic achievement than higher SES youth (McLoyd, 1998), it is possible that the primary-to-secondary education transition is especially stressful for this group of children. Moreover, because far more ethnic/racial minorities tend to live in poverty (Brooks-Gunn, Klebanov, & Duncan, 1996), it is also pertinent to consider how the transition may impact ethnic and racial minorities' academic achievement. Illustratively, Simmons et al. (1991) found that grades of African American students were extremely low following the secondary education transition, even though all students grades declined. Serbin et al. (2013) investigated academic achievement across the secondary transition in an "at risk" sample of children from lower income families. Findings indicated that family resources and child gender mattered: children from families with fewer resources had lower achievement than those from families with more resources following the transition, and girls had higher grades than boys following

the transition. Moreover, multiple mediation analyses demonstrated that the link between gender and achievement was mediated by children's social and academic skills (i.e. spelling), as well as the degree of support they received from parents prior to the transition. Thus, social skills, academic skills, and support from parents prior to the transition contributed to differences in boys' and girls' achievement following the transition into secondary education. Future work should focus on prevention and intervention efforts for populations of children that may especially need help to navigate the secondary education transition and to excel in school.

The effects of the transition to secondary education on emotional health

The second key indicator of a successful transition to secondary education in Figure 1 is emotional health. Adolescence is a significant period for the development of mental health disorders with symptoms often increasing during this time (e.g. Kessler et al., 2005). A report by the Office for National Statistics states the prevalence of mental health disorders to be 12% in children aged 11-16, compared to 8% of those aged 5-10 (see Green, McGinnity, Meltzer, Ford, & Goodman, 2005). The Australian National Survey of Mental Health and Well-Being supports this figure reporting that at least 14% of adolescents younger than 18 were diagnosable with a mental disorder (Sawyer et al., 2001). Given the high frequency of disorders within this age range, it seems likely that the primary-to-secondary education transition could contribute to mental health issues among young adolescents. In this section, we review this possibility.

What do we mean by emotional health?

If we consider emotional health in terms of constructs identified by mental health practitioners (APA, 2017a), then there are broadly two categories of symptom clusters to consider: symptoms that are largely internal to the person (that manifest in psychological constructs such as anxiety and depression) and those that are external to the person (that manifest in constructs such as conduct problems and attention-deficit and hyperactivity). Before looking at predictors of these symptoms related to the transition to secondary education, we will review these symptom clusters.

Internalising symptoms

One of the most common childhood disorders is anxiety. Anxiety disorders can take many forms and are generally characterized as feelings of tension and worrisome thoughts as well as physiological changes including an increased heart rate, increased perspiration and trembling among others (APA, 2017a). Anxiety is reported to be the earliest disorder to emerge in childhood, with 50% of anxiety disorders beginning by age 6 in affected adolescents (Merikangas et al., 2010). Additionally, when averaged across all subtypes of anxiety disorders, the median age of onset is 11 years (Kessler et al., 2005). Furthermore, it is one of the most common disorders faced by children; one meta-analysis of 41 studies spanning 27 countries conducted between 1985 and 2012 estimated the worldwide prevalence of any anxiety disorder to be 6.5% (Polanczyk, Salum, Sugaya, Caye, & Rohde, 2015). Moreover, the lifetime prevalence of any anxiety disorder appears to be a staggering 31.9% (Merikangas et al., 2010). Childhood anxiety also has a higher prevalence than depression and is diagnosed more frequently

than behavioral issues such as conduct disorder (Cartwright-Hatton, McNicol, & Doubleday, 2006).

Most anxiety disorders are already established by early adolescence (Kessler et al., 2005) with little change in frequency from age 13/14 up to age 17/18 (Merikangas et al., 2010). The transition to secondary education typically occurs just before this period of a child's life and is arguably particularly important in this process. For example, students experiencing greater worries concerning the school environment and relationships over the transition typically have heightened anxiety symptoms (Akos & Galassi, 2004; Arowosafe & Irvin, 1992; Harter et al., 1992; Lucey & Reay, 2000). Greater school transition concerns both prior to and following the move have been associated with increased anxiety (Rice, Frederickson, & Seymour, 2011), though research to date has been somewhat sparse and inconsistent.

A longitudinal study of U.S. schoolchildren aged 11-13, showed a decrease in anxiety symptoms following the move to secondary education (Grills-Tauchel, Norton, & Ollendick, 2010). This decrease in social anxiety was significant only in males. Furthermore, anxiety symptoms were predicted by global self-worth and social acceptance, with higher levels of both predicting greater decreases in anxiety, with males again showing greater declines. This finding suggests the transition could be particularly beneficial for male students in reducing their anxiety. One reason proposed to explain this gender difference is that females tend to participate in "relational" forms of bullying such as gossiping, spreading rumors, and excluding peers (Crick & Grotpeter, 1995; Murray-Close, Ostrov, & Crick, 2007). This may be an underlying mechanism of why girls experience greater social anxiety compared to boys, given

females place greater value on close friendships, and greater fear of rejection and the loss of relationships (for a review, see Rose & Rudolph, 2006). Additionally, Grills-Taquechel et al. (2010) reported lessened impact of the transition on individuals with high self-worth and those who felt more socially accepted by their peers. Meanwhile, there also appears to be links between anxiety, stress, and the transition. Zandstra, Ormel, Nederhof, Hoekstra, and Hartman (2015) reported a negative transition experience was associated with declines in mental health well-being, evident only in individuals with high awakening cortisol, a hormone important for stress reactivity. This association suggests that some individuals may be predisposed to greater emotional responses following a negative event such as the secondary education transition. This may help to explain why some individuals transition successfully, while others do not.

In a Canadian cohort of 11-year-old pupils, Duchesne, Ratelle, Poitras, and Drouin (2009) found that anxiety predicted both academic and teacher worries preceding the transition to middle school. Further analysis suggests girls perceived themselves as being more anxious and also reported greater worries about meeting academic demands and establishing relationships with teachers. However, attachment predicted anxiety levels, with individuals reporting more 'secure' attachments showing lower anxiety levels. Alternatively, another study of over 200 English schoolchildren (age 11) found similar levels of anxiety both at the start of secondary education and at the end of their first year (Riglin et al., 2013). There were further gender differences with females experiencing higher general anxiety and school anxiety, greater school concerns, and increased school engagement compared to males, whereas, conduct disorder was higher in males than females. However, there were no measures prior to

the transition in this study (e.g. in Year 6) making it impossible to draw conclusions about the effect of the transition.

Where evidence is inconsistent concerning the emergence of general anxiety following the transition to secondary education, there are links between the changeover and the development of one domain-specific type of anxiety: maths anxiety. Maths anxiety is often defined as feelings of tension, apprehension, or fear that may interfere with maths performance (Ashcraft, 2002). Maths anxiety has been found to increase at the time of the changeover for students that transitioned to a new secondary school compared to those that did not and increased especially in females and high-achievers (Madjar et al., 2018b). Their analysis suggests there is a significant increase in maths anxiety toward to end of primary education, which remains high for some time, before decreasing at the end of their first year in secondary education back to initial levels. This suggests that the transition to secondary education may be an important period for interventions for these groups because maths anxiety has been linked to GPA and maths ability (Madjar et al., 2018b).

A second kind of internalising disorder is depression. Depression is closely associated with anxiety that manifests in several symptoms most commonly including feelings of sadness, lack of interest and pleasure in activities, lack of energy and concentration, feelings of worthlessness, and recurrent thoughts of suicide (APA, 2017b). The prevalence of major depressive disorder (MDD) by age 14 is 8.4% (Merikangas et al., 2010), a figure that almost doubles to 15.4% from age 13-14 to age 17-18 suggesting that adolescence is a critical period for developing depression. Further support for this argument comes from reported increases in suicidal ideation at a similar

age to the transition to secondary education (Adrian, Miller, McCauley, & Vander Stoep, 2016).

Similar to the evidence regarding the transition to secondary education and anxiety symptoms, research on depression in this context is also somewhat sparse. Nevertheless, depressive symptomology is highly stable throughout adolescence, however, stability significantly drops during the transition from 6th to 7th grade coinciding with the transition from primary to secondary education (Tram & Cole, 2006). Rice et al. (2011) further report positive associations between depression and post-transition school concerns.

Additionally, in a study of over 2000 Scottish pupils, West, Sweeting, and Young (2010) reported that poorer transitions at age 11 (including both school and peer concerns, such as increased workload and bullying) predicted depression at age 13 and 15, while peer concerns at age 13 was weakly associated with psychological distress at age 18 (OR = 1.19). Their results contradict Kingery, Erdley, and Marshall (2011), whose data shows depression significantly decreases following the transition. However, the sample in Kingery's study included mostly Caucasian children residing in small, rural, suburban communities which may make generalizability to children studying in urban districts, or those from ethnically diverse backgrounds, problematic.

While the conclusion is somewhat unclear, depressive symptoms are important to keep in mind because Riglin et al. (2013) reported greater levels of depression at age 11 predicted academic achievement at the end of individuals' first year of secondary education. However, when controlling for conduct disorder, this effect was no longer significant. Additional gender effects were evident with depression being significantly

associated with poorer academic achievement for males only. The mediating effect of conduct disorder between depression and achievement further highlights that emotional problems and academic achievement are not independent outcomes, and that declines in one area often coincide with declines in other domains.

Although the evidence linking the transition to secondary education to mental health outcomes is sparse, there is a larger body of research linking it to psychological attributes such as self-esteem, self-efficacy, and self-concept (e.g. Coelho et al., 2017). Though there are slight differences in meaning, these variables can be broadly defined as attitudes, beliefs, and models of a person's own abilities, and their capability to perform such behaviors in a given situation (APA, 2017c). These concepts may be informative with respect to mental health outcomes because they have been linked to well-being, academic achievement, and other educational benefits (e.g. Diener & Diener, 1995; Marsh & Craven, 2006).

In a study of over 1100 Portuguese students, Coelho et al. (2017) reported decreases in academic self-concept, physical self-concept, and self-esteem after the primary-secondary education transition. The effect remained significant when controlling for gender. However, the school transition occurs slightly earlier in Portugal: as young as 9 years old. Additionally, self-esteem has been found to decrease during transitionary years and continues to decline post-transition (Arens et al., 2013b; Seidman, Lambert, Allen, & Aber, 2003). This decline is supported by Schaffhuser et al. (2017) who also reported decreases in self-esteem as well as academic and behavioral self-concepts over the transition. Moreover, student self-efficacy appears to be positively associated with teacher-rated overall school adjustment, as well as pupil-

rated post-transition relationships with teachers (Bailey & Baines, 2012). In addition, West et al. (2010) indicated self-esteem may act as a predictor of adjustment, with individuals low in self-esteem prior to the transfer experiencing a poorer transition to secondary education with greater school and peer concerns. Despite a general consistency in the transition having a negative effect on self-esteem, Kingery et al. (2011) report the opposite: self-esteem increased following the transition.

To summarize, the evidence concerning the impact of the transition on psychological outcomes has been inconsistent. While some researchers have concluded the transition is detrimental to emotional well-being and psychological attributes, others disagree. One consistent finding across domains is the effect of the transition is heightened for individuals expressing greater concerns before the changeover. It appears that adolescents who express more worries regarding the transition are more likely to suffer poorer transitions compared to their peers. In addition, compared to boys, girls have been reported to experience a poorer transition, with heightened levels of anxiety, and greater concerns over relationships and workload (e.g. Duchesne et al., 2009; Riglin et al., 2013). In the Section “Externalizing Symptoms and Anti-Social Behaviors,” we describe a separate category of emotional health symptoms, externalizing symptoms, and predictors of these symptoms that relate to the transition to secondary education.

Externalizing Symptoms and Anti-social Behaviors

Externalizing disorders can include a range of disruptive behaviors including conduct disorder, aggression, attention deficit hyperactivity disorder (ADHD), and oppositional behavior. Although such issues can often be disruptive to the learning environment in the classroom itself, they are also related to negative outcomes for the

individual including low achievement, school dropout, and non-completion of further education (Adams, Snowling, Hennessy, & Kind, 1999; Finn, Fish, & Scott, 2008; McLeod & Kaiser, 2004; Reid, Gonzalez, Nordness, Trout, & Epstein, 2004).

There is a lack of research examining externalizing disorders and anti-social behaviors resulting from the primary-secondary education transition, although evidence suggests that the transition is an important event that may exacerbate the effects of externalizing disorders on educational outcomes. For example, Palmu, Närhi, and Savolainen (2018) reported associations between conduct disorder and ADHD on academic performance during the transition to secondary education. In a study of over 300 12- to 13-year-old pupils in Finland, their results found externalizing behaviors were associated with a decrease in GPA, particularly, ADHD before the transition negatively affected GPA post-transition. Riglin et al. (2013) support this link with conduct problems prior to the transition associating with academic achievement post-transition. Additional analyses suggested that conduct problems pre-transition were also associated with a decrease in school liking following the move.

West et al. (2010) found higher levels of aggression were associated with poorer school transitions, but better peer transitions. Furthermore, aggressive behavior predicted academic expectations for secondary education as well as academic functioning post-transition (Cillessen & Mayeux, 2007). Aggression appeared to interact with peer status such that there was no significant effect of aggressive behavior on academic functioning in individuals with high popularity. Conversely, adolescents with low popularity and high aggressive behavior were more likely to experience lower academic functioning.

It is evident that there are individual differences. For example, three types of aggressive behavior trajectories have been identified over the transition including low-stable, decreasing, and increasing (Malti, McDonald, Rubin, Rose-Krasnor, & Booth-LaForce, 2015). Membership to a group was altered by the child's views on friendships. Specifically, those who had less of an understanding of the value of trust and reciprocity within friendships were more likely to be in the increasing trajectory group. This highlights the importance of relationships with other individuals around the time of the school transition and may be a protecting factor against maladaptive outcomes.

Predictors of emotional health

The review above demonstrates that the school transition impacts a wide range of emotional health outcomes and adolescent behaviors; however, the success of the transition can also be influenced by a number of other factors under the categories identified in Figure 1. These additional influences can increase or decrease the risk of a poor transition and include the individual's social network (family, peers, and teachers), special educational needs (SEN), as well as gender and pubertal status. Generally, the children most at risk of poor transitions are children recognised as having SEN and those with a poor social network.

Environment-level predictors. As children progress to secondary education, they often face a substantially different environment compared to the one that they have been used to. This environment includes larger classrooms and school buildings to navigate, and different social networks. The move to secondary education also leads to changes in the educational goal structure toward performance-based goals (Madjar et al., 2018a). In a study of 415 schoolchildren (aged 11-12), Madjar et al.

(2018a) investigated goal orientations following the transition to secondary education. At present there are three commonly identified academic goals including: mastery-approach, which involves learning to acquire knowledge and skills; performance-approach, which involves demonstrating greater skills relative to others; and performance-avoidance, which involves avoiding demonstrating such skills. Madjar et al. (2018a) argue that the transition from primary to secondary education coincides with a change from a mastery goal structure, to a performance goal structure post-transition. Further research provides evidence for performance goal structures being detrimental to school engagement (Madjar & Chohat, 2017). These results suggest that the school transition may increase competition between individuals, and not always for the better (see Johnson, Maruyama, Johnson, Nelson, & Skon, 1981). Transitioning schools could focus more on continuing to provide a mastery goal structure given its importance for engagement, school performance, and general learning (see Kaplan & Maehr, 2007). Otherwise, this change in goal structure may increase the risk of school disengagement post-transition, which can already be a common issue as teens grow older.

Duineveld, Parker, Ryan, Ciarrochi, and Salmela-Aro (2017), who studied the secondary education transition in Finland, reported decreased depressive symptoms, decreased life satisfaction, and increased emotional exhaustion following the transition. In terms of the home environment, they found that mothers provided greater autonomy support (i.e. supporting the child's self-governance and control over their life; Keller, 2016) compared to fathers prior to the transition. Moreover, Duineveld et al. (2017) reported greater levels of autonomy support before the transition significantly predicted a decline in depression after children moved to secondary education. This finding indicates that autonomous, supportive parenting that encourages independence may

protect children from developing mental health disorders during the transition to secondary education.

Related evidence provides support for child-mother attachment predicting perceived academic competence and anxiety during the middle school transition (Maltais, Duchesne, Ratelle, & Feng, 2017). The protective power of attachment has also been argued to moderate the relationship between a social comparison learning environment in the classroom on anxiety symptoms (Maltais, Duchesne, Ratelle, & Feng, 2015). Furthermore, in a study of transitioning students, Booth-LaForce et al. (2012) reported that high-increasing growth in anxious withdrawal was predicted by low parental autonomy, low time spent with the mother, both restrictive and nurturing parenting, and peer exclusion. These findings further support the links between a positive, supportive social network, and adolescents' behavioral outcomes during the transition.

Individual-level predictors. Social support is vital for early development, learning, and psychological well-being (e.g. Demaray & Malecki, 2002). Perceived social support can be very important during adolescence where individuals experience rapid changes biologically, emotionally, and socially. In addition, a positive social support network can also be protective of issues arising during the transition to secondary education. As we have mentioned above, parental support may buffer children from the emotional effects of the transition to secondary education (presumably through positive effects on the child's social schema). The vast majority of research looking at the emotional impacts of the transition to secondary education has looked at variables that we have clustered as indicators of a child's social schema in Figure 1.

First, peer relationships facilitate a positive transition on a range of adaptation measures. For example, Kingery et al. (2011) found that pre-transition positive peer relationships (e.g. peer acceptance, friendship quality, number of friends) predicted various positive post-transition well-being measures including academic achievement, loneliness (or lack of), self-esteem, and school involvement. Cantin and Boivin (2004) reported the transition to secondary education was associated with an increase of perceived social acceptance, as well as an increase in supportive relationships with their school friends. The increases reported were related to friends providing greater instrumental support, informational support, and emotional support. The effects remained in the following 2 years of school following the move. These findings further highlight the importance of friendships and peer relationships during the progression to secondary education.

In addition to the reorganization of children's friendship networks, there is also evidence that the transition may provide new opportunities for victimized children. Wang, Brittain, McDougall, and Vaillancourt (2016) argued that victimization decreased for females following the school transition compared to girls that did not transition. Though, transition status made no difference in male victimization between the two time points. Additionally, exclusion and victimization have been argued to decrease following the transition on average, with those recognized as anxious-solitary youth experiencing greater relative declines (Shell et al., 2014). This idea supports the notion of secondary education providing a chance for children to alter their identity as a victim which they may have been associated with in primary school, and also provides the opportunity for children to find new friends or change social groups to one which is more positive and supportive. Cantin and Boivin (2004) also state that around 61% of

school peer ties identified prior to the transition no longer remained following the move, further reinforcing the idea that children renegotiate their social network.

Overall, there is general support that a positive social network is important for children's well-being during the transition to secondary education, but children also require support from their teachers and school to feel more secure in their new environment.

A second protective factor against negative emotional outcomes includes school connectedness and belongingness (affect to school in Figure 1). For example, Vaz, Falkmer, et al. (2014) studied 266 Australian pupils, and reported increases in school belongingness resulted in decreases in mental health problems, even when controlling for prior mental health. Moreover, in a comparison study between transitioning and non-transitioning schools in Australia and Denmark, respectively, Nielsen et al. (2017) reported no significant difference in school connectedness in transitioning schools as pupils aged, whereas schools that did not transition experienced significant decreases in school connectedness over time. However, it may be important to highlight that although the number of "disconnected" students in the transitioning sample was similar across all age groups, this was close to significance in the transition year with increased odds of disconnectedness. This means that, although not statistically significant, there was a trend toward disconnectedness increasing during the transition year.

A third aspect of social schema is the relationship to teachers. After the transition to secondary education, children tend to have different teachers for each discipline, compared to having a single teacher in primary education. It can be difficult for children to form relationships with their new teachers as strong as those held previously. This

change in their social network may be detrimental given preadolescents' need for guidance and support during this time (Eccles & Roeser, 2009). In addition, students have been found to possess a greater reliance on teacher support and a preference for external direction following the transition to secondary education (Robbers, Donche, De Maeyer, & Van Petegem, 2018). This change in the type of relationship with teachers has been notably recognised as one of the concerns amongst children moving into secondary education (Duchesne et al., 2009).

Research findings concerning teacher relationships have been somewhat mixed. Martínez et al. (2011) describes how both social and teacher support significantly decline over the transition. Bru, Stornes, Munthe, and Thuen (2010) also reported a general decline in perceived teacher support over the school years, nevertheless, they argue there is no obvious abrupt change during the time between primary and secondary education and criticize previous studies for not accounting for age-related differences. Despite mixed findings, teachers are likely to be an important part of the child's social and support network, which we have seen is important for promoting well-being. Future research could therefore do more to look at the role of teachers within the child's support network. For example, it would be beneficial to have research evaluating whether making student-teacher relationships and student-teacher support networks similar to those experienced in primary education leads to improved outcomes after the transition to secondary education.

Contextual predictors. The previously described issues of declining social support and the different school climate are faced by every student. However, it is clear some students face additional difficulties when adjusting to secondary education,

this includes children with SEN. SEN refers to children who have learning problems or disabilities that may make it difficult to learn relative to other children their age. This can include difficulties in reading and writing, behavioral issues, difficulty understanding or expressing themselves, as well as physical ability issues which may affect them while in school.

The school transition can be especially problematic for children with SEN. For children with sensory or mobility difficulties, solely moving between classes can be challenging, especially so in an unfamiliar environment such as a large, novel secondary school. Children with behavioral or emotional issues may have difficulty establishing relationships with teachers and peers, leaving them feeling isolated. With high importance placed on discipline and obedience to authority in secondary education, children with behavioral or emotional difficulties may be perceived by teachers as acting out or “troublemakers” when in fact they have different needs and requirements.

Fortunately, recent research has attempted to investigate the effects of the school transition more thoroughly for children with SEN, with the aim of identifying the most common issues and difficulties they may encounter during this change. In a systematic review examining the effects of the school transition for children with SEN, Hughes, Banks, and Terras (2013) investigated psychosocial functioning including internalising functioning, self-concept, self-esteem, self-confidence, externalizing functioning, and social functioning. They identified key findings of a higher likelihood of victimization and bullying, poorer social adjustment (i.e. loneliness) and lower levels of perceived social support relative to typically developing children. Furthermore, children reported additional concerns and worries. These concerns referred to the provision for special

needs in their new school, the ability to make friends, increased workload, and greater worries of bullying relative to their peers without SEN.

Since Hughes et al. (2013) conducted their review, a number of additional studies have been published finding similar results. First, Akos et al. (2015) reported less growth in both maths and reading during the transition year for SEN students despite having the largest year-to-year growth in the year prior to the changeover. Further research also reports individuals with disabilities display significantly lower academic competence compared to their typically developing peers pre- and post-transition (Vaz et al., 2014). Though interestingly, adolescents with a disability showed an improvement in academic competence over the transition compared with other pupils. Conversely, disability status was linked to decreased mental health functioning pre- and post-transition. It is evident that adolescents with SEN have different requirements to consider when moving to secondary education to ensure a successful transition. Neal, Rice, Ng-Knight, Riglin, and Frederickson (2016) endorse a personal approach when designing transition strategies especially for children with SEN.

With respect to other potential contextual variables, gender has been found to predict adaptation to secondary education. This finding is not surprising given that (1) males and females develop at different rates during adolescence; and (2) internalising disorders are more prevalent in females than to males (Kessler et al., 2005; Merikangas et al., 2010). Coelho and Romão (2016) found that females experienced significantly higher academic and peer-related stress during the school transition compared to their male peers, whereas males reported higher stress regarding teachers and rules. Furthermore, females had significantly greater increases in peer-related stress during the

transition. Grills-Taquechel et al. (2010) supported this conclusion with results suggesting that males experienced a significant decrease in anxiety during the transition to secondary education whereas girls did not. In addition, girls experienced significantly greater general and school anxiety pre- and post-transition. Females also reported a higher number of school concerns, but greater school liking and fewer conduct problems pre- and post-transition (Riglin et al., 2013). Rice et al. (2011) also found school concerns were higher for females both prior to and following the transition. This finding is also supported by Smyth (2016) who reported that girls were more likely than boys to experience transition difficulties.

Furthermore, girls are more likely to experience maths anxiety over the transition to middle school. Madjar et al. (2018b) found that girls reported higher maths anxiety following the transition to secondary education which later decreased to initial levels 1-year post-transition, whereas maths anxiety reported by boys remained stable during this time. This is an important finding as maths anxiety has been argued to have a bidirectional relationship with maths performance (Carey, Hill, Devine, & Szűcs, 2016). Consequently, if maths anxiety increases for girls during this time it may also impact their later performance, which in turn may increase their anxiety toward maths. Schaffhuser et al. (2017) also argued females are more negatively impacted by the transition compared to males. However, it is not entirely negative for females whereby girls in fact report higher academic and social functioning post-transition relative to boys (Cillessen & Mayeux, 2007). On the other hand, Kingery et al. (2011) reported no gender differences in the overall adjustment to secondary education.

In addition, females tend to experience pubertal onset earlier than males (Lee, 1980) which can have interesting interactions with the effect of the school transition. As described above, females tend to experience greater stress levels around the transition which is also around the time of pubertal onset. Koenig and Gladstone (1998) reported higher rates of depression among developing females (i.e. those that had started or in the latter stages of pubertal development) during the transition years, whereas rates among males were stable over time. However, it is important to note that this was examined in a high school sample as opposed to the earlier transition of middle school/secondary education. By the time of the transition in this sample, a large number of females had already fully developed.

Discussion

The aim of this review was to assimilate the findings to date concerning the impact of the primary-to-secondary education transition on both academic and psychological outcomes. Overall, there appears to be some negative impacts of the transition, though it is difficult to conclude definitively because there are many inconsistencies in the data. These conflicts are not unexpected given the multitude of interacting factors that exacerbate or mitigate the impact of the transition. However, there are still some findings worth noting.

Firstly, the transition to secondary education appears to have some negative consequences for academic achievement (Alspaugh, 1998; Alspaugh & Harting, 1995; Felner et al., 1981; Gutman & Midgley, 2000). Upon transitioning, students must adjust to larger schools and class sizes, greater academic independence, navigating new teacher and peer relationships, higher teacher expectations, and a bigger emphasis on

grades and performance. These differences require children to adjust to new academic expectations, norms, and evaluation criteria. These differences can adversely impact young adolescents' academic motivation and engagement, academic self-concept or competence, affect toward school and learning, and their intrinsic interest in school (Eccles & Midgley, 1989; Eccles et al., 1984; Harter, 1981; Skinner, Zimmer-Gembeck, Connell, Eccles, & Wellborn, 1998). Individual difference factors including cognitive and emotional ability levels, gender, and SES can moderate associations between these factors and future academic achievement following the secondary education transition.

With respect to children's emotional health, the evidence was inconsistent. Some researchers found significant negative impacts on emotional well-being post-transition, while others found positive outcomes, or negligible results. Clearly, we need a better understanding of the interplay between the constructs identified in Figure 1 to get a handle on what moderates the effect of the transition on emotional health.

Several risk and protecting factors were identified to play an important role in the transition. First, things likely to affect the child's social schema were found to be particularly important over the transition, including social support received from parents, teachers, and peers. During the transition, children often renegotiate their friendship groups and report decreased general social support during this time. Cohen and Wills (1985) reviewed two main explanations for the role of social support during stressful situations: first, that social support acts as a buffer against stress and second, that solely being part of a social network is helpful for the individual. Their review found support for both explanations, suggesting social support provides various benefits during stressful events and daily life. These ideas may also support the evidence

discussed in relation to the importance of social networks around the transition to secondary education. Due to the heightened stress felt by children during this time, social support may help them feel more secure and socially accepted. Parents and teachers should be made aware of the perceived decline in social support reported by adolescents and aim to provide additional support when required to allow for the best outcomes. Despite perceived declines in parental support and perceived increases in peer support during the transition, it is parental support that most accurately indicates emotional difficulties in adolescents (Helsen, Vollebergh, & Meeus, 2000). Waters, Lester, and Cross (2014) support this finding, concluding that parental presence at home before and after school is the most significant predictor of a positive transition experience.

Additionally, the school and class environment can elicit negative outcomes. For example, children report higher performance-based goals in secondary education compared to the mastery approach in primary education. A performance-approach increases competition between individuals whereas a mastery approach focuses on learning and working with the purpose of gaining knowledge. This change can be harmful to engagement which is an important aspect to sustain during the transition.

Furthermore, some individuals are more “at-risk” of a poor transition relative to their peers. Those most affected include children with SEN. First, children with SEN may face additional difficulties during the move, including matters that may be seemingly straightforward such as transport and mobility, an issue that is usually not as applicable to typically developing children. Furthermore, the findings suggest children with SEN overall report higher victimization, poorer adjustment, lower levels of social

support, and reduced academic growth during the transitional year. There are also noteworthy gender differences. The research suggests that females are arguably more affected by the transfer. Girls report higher rates of school concerns, as well as experiencing higher levels of anxiety and depression (in line with other research findings of higher rates of emotional and mood disorders in the adult population among females). Conversely, boys report higher concerns regarding rules and teachers, as well as higher rates of behavioral and conduct problems compared to females.

Theoretical explanations

Ideally, we need a theoretical model to explain how environment-level constructs create changes in the child's individual-level schema, how environment-level constructs directly affect academic and emotional outcomes, and how individual-level schema affect academic and emotional outcomes. It is a tall order. There are too many potentially relevant theoretical frameworks to cover in one paper, but we can use the example of anxiety to look at how theories of emotion might prove useful.

First, we can look to these models to explain why the transition to secondary education might increase anxiety. Recent research has found very little evidence for the genetic transmission of anxiety, which implies that most risk comes from environmental transmission (Eley et al., 2015). Given that children spend a considerable proportion of their day in school, the school environment is likely to be a potential anxiety trigger. Learning theories suggest that anxiety is acquired through an association-based system in which stimuli and situations come to evoke fear through direct association with fear-evoking experiences, verbal threat information, and observational learning (Field & Purkis, 2011; Mineka & Zinbarg, 2006). The aforementioned shift to performance-

based goals in secondary education, heightened teacher expectations, and lower teacher support may be associated with more verbal threat information (“if you don’t perform well, you won’t get a good job”), more direct negative experiences (e.g. being told off, or social humiliation, when performance is below what is expected), and more observational threat learning (observing others being told off or humiliated when they perform below expectations). Research supports the idea of performance-goal structures creating anxiety: goal structure has been linked to maths anxiety (Federici, Skaalvik, & Tangen, 2015; Skaalvik, Federici, Wigfield, & Tangen, 2017) and Baudoin and Galand (2017) reported that performance-based goal structures were associated with feelings of shame and anxiety in schoolchildren. These heightened expectations and associated threat messages at school may be mirrored in the home environment and may be exacerbated by certain parenting styles known to increase anxiety, such as over-critical parenting (Creswell, Cooper, & Murray, 2010).

Given that there is a theoretical route through which the transition could create anxiety, then we can look at the effect that this anxiety might have on the individual-level constructs. Heightened anxiety is associated with patterns of information processing (Hadwin & Field, 2010) such as a tendency to interpret ambiguity in a threatening way (interpretation bias) and a tendency to attend to threat in the environment (attentional bias to threat). As such, once anxiety is heightened students may attend more to both negative feedback about performance (which may negatively affect learning schema and academic self-concept) and negative social cues (which will affect social schema). Equally, ambiguity about academic and social matters may be interpreted more negatively. In short, the knock-on effect of a transition that creates anxiety will be a processing style that is likely to impact social schema, learning

schema, and academic self-concept. Those already prone to anxiety are most likely to experience more anxiety, and greater biases in their information processing, which would lead to more anxiety. This idea is supported by Lester, Lisk, Carr, Patrick, and Eley (2019) who found that children with greater interpretation bias toward threat experienced higher levels of anxiety before transitioning to secondary education. Of course, this theory also explains variance in the levels of anxiety following the transition (e.g. Grills-Taquechel et al., 2010; Lester et al., 2019; Madjar et al., 2018b), because there will be variance in the negativity in secondary environments and variance in children's risk for anxiety.

For children for whom the transition creates anxiety (and shifts in their schema and information processing), the attentional control theory, which suggests that anxiety impairs goal-directed attentional systems, offers a theoretical mechanism for why academic performance would be affected (Eysenck, Derakshan, Santos, & Calvo, 2007). One key assumption of this theory is that anxiety increases the attentional allocation toward threat-related stimuli including both external and internal stimuli (i.e. worrisome thoughts). This theory can explain why the anxiety-inducing transition impairs academic outcomes by reducing the attentional capacity available for cognitive tasks. For example, a child experiencing anxiety because of the transition will allocate less attention to tasks in the lesson, and more attention toward worrisome thoughts, and as a result will perform worse in class. This model has been supported by research conducted on maths anxiety and performance (e.g. Carey, Devine, Hill, & Szűcs, 2017). Maths performance is arguably more affected by anxiety as it requires significant executive function skills (Cragg & Gilmore, 2014), and as anxiety takes up the allocation available, the executive function systems required to perform maths tasks

efficiently are put under strain and performance on the task diminishes, resulting in poorer academic achievement. The attentional control theory also supports the links found between emotional well-being and academic performance.

The theories of anxiety we have used are illustrative of how psychological theory can and, probably, should be used to try to construct parsimonious theoretical frameworks for the effects of the transition to secondary education. Of course, the theories we chose offer little explanation of depressive symptoms, conduct problems and so on. The point is simply that it is possible to build on well-established psychological theory to explain the interplay between the constructs reviewed in this paper.

Implications for school intervention strategies

The above findings have implications for school-based intervention programs that target the primary-to-secondary education transition. At present, these programs are free to vary between schools and districts and often attempt to improve self-confidence and problem-solving (e.g. Shepherd & Roker, 2005). To date, a few studies have examined the impact of different school programs over the transition to investigate whether this makes the transfer easier for students. One study found systemic strategies (e.g. group work on projects with future classmates and modules taught continuously over the transition) were associated with lower school anxiety, though only in typically developing children (Neal et al., 2016). In addition, Rosenblatt and Elias (2008) found that U.S. children who took part in an intervention focusing on social-emotional learning before transitioning had a smaller decline in GPA when receiving higher dosages of the intervention compared to a low dosage group. Furthermore, Shepherd

and Roker (2005) investigated a project run after-school which aimed to build self-esteem and resilience in particularly withdrawn and shy children and found improvements in both self-esteem and social skills and fewer school concerns.

While several interventions focus on social-emotional development and improving social skills, only a small number of studies have investigated ways to improve educational achievement. One study conducted by Siddiqui, Gorard, and See (2016) evaluated a reading program following the transition that was undertaken by pupils who had not reached the expected level for English in their final year of primary education. Their results found that children receiving the intervention had higher reading scores compared to a control group. However, in an earlier study, Siddiqui, Gorard, and See (2014) evaluated a summer school program that focused on literacy and numeracy skills and found it was not effective in improving the educational achievement of “at-risk” students.

While it is clear some of these programs have benefits for students, much more research is needed to assess the effectiveness of different types of intervention programs with greater sample sizes and longitudinal investigation. Based on the evidence presented, future programs should focus on increasing perceived social support (including that given by parents, teachers, and peers), continuation of academic study, such as introducing topics in the final year of primary education that are continued through to secondary education, and developing social-emotional interventions that can be administered nationwide which are effective for typically developing children and those with SEN. In addition, the difficulties associated with the transitional period could be eased by preparing children for the change in goal structure, or by secondary schools

adopting a mastery environment, which is arguably more beneficial for children's learning (Meece, Anderman, & Anderman, 2006).

Limitations

Many of the studies presented here were conducted several years ago, often using longitudinal data collected years prior, which may decrease the relevance to education and schools today. This limitation highlights the need for more research to examine how the changes in our educational systems and the advancements made particularly in schooling and technology may impact both the well-being of students and their learning environment during the transition to secondary education. For example, in comparison to transitional students that participated in studies conducted in the early 2000s, it is now the norm for adolescents to own, or have access to a mobile phone, computer, or tablet (Ofcom, 2017). To date, very few studies have investigated the use of the internet in transition interventions (e.g. Maher, 2010), and it appears there is a lack of investigation into the effects of technology on well-being and achievement during the transitional years. Current investigation into this area is important for a number of reasons. One example to illustrate this is bullying. Advancements in technology have made bullying an online activity resulting in around 49% of children being victims of cyberbullying (Raskauskas & Stoltz, 2007). As discussed previously, the transition may help victimized children renegotiate their social network to no longer be victims of bullying (e.g. Shell et al., 2014; Wang et al., 2016). However, it could be speculated that if evidence of the bullying that occurred during primary education was online, the renegotiation of their social network would not be able to occur, and as such, victimized children would continue to experience bullying throughout secondary

education. Another example is the use of the internet to facilitate the transition in a practical manner, i.e. showing interactive maps of the school environment and classrooms to prospective students. An online, interactive map may be beneficial as one of the worries reported by transitional students was being lost (Zeedyk et al., 2003). Another potential use of technology is inviting classroom peers to get to know each other by using a monitored forum where children may introduce themselves and ask their new teacher and a few current students any questions they may have. Additional homework to be completed over the summer prior to the transition could be made available on such a forum to help decrease the interruption in achievement found during the transitional years (Akos et al., 2015). While the above points made are based on speculation alone, future research examining some of these ideas could provide interesting insights into the use of technology during the transition year to help facilitate a successful transition in terms of student well-being, social interaction, academic growth, and environmental practicalities.

Another limitation is the lack of cultural diversity within the research discussed. The studies presented here have focused on particularly “western systems” such as those in America, Europe and Australia. One reason for the lack of diversity is the differences found in systems around the world. For example, children attending schools in places such as Mexico, Africa, or the Middle East, are less likely to attend school past the age of 11 (Gibbs & Heaton, 2014; UNESCO Institute for Statistics, 2010), therefore making the secondary education transition a non-event. However, one of the Sustainable Development Goals set out to achieve by 2030 by the United Nations is to ensure all children complete primary and secondary education. Hopefully, this increase in attendance worldwide allows for comparisons of the transition to be made in the future,

allowing for research from a range of culturally diverse countries to examine the issues children encounter during this time, and whether they differ between nations.

Conclusion

The importance of emotional well-being, specifically within schools, has been acknowledged by the British Psychological Society in a recent briefing paper (BPS, 2017). It is reported that one in four children and adolescents display signs of a mental health difficulty, with up to three children in every classroom experiencing a mental health issue that can be treated. Furthermore, only 25-40% of the young people affected by these issues receive support from a mental health professional early enough in their development, if they receive any help at all. As most of the disorders experienced in childhood and adolescence continue into adulthood, it is beneficial for everyone involved to ensure interventions are administered as early as possible not only for better emotional well-being but also because of the associations with academic achievement and social functioning, all of which are important for a successful transition. To help during this time, parents and schools could aim to provide more social support during and following the transition to increase the perceived support felt by adolescents. Schools could also provide transition strategies that focus on the worries of children such as being lost or being bullied. In addition, schools could teach topics that can be carried on from primary to secondary education to help with the interruption of achievement. Furthermore, children with SEN should have additional support and provisions in place to ensure they transition with as few difficulties as possible.

Despite all the evidence presented, there are still gaps in the literature. The research investigating internalising and externalizing disorders is particularly sparse and

should be the focus for future exploration. Furthermore, researchers should pilot transition strategies in schools based on the recommendations above. Additional research should aim to utilize longitudinal designs measuring a wide range of factors to accurately assess the impact of the school transition on several outcomes including academic achievement and emotional well-being. Hopefully, future research will overcome the inconsistent findings to date and will reliably identify factors that ensure children become well-adjusted to their new environment. By identifying predictive factors of importance for the primary-to-secondary school transition, researchers can help enable every child to have the opportunity to make a successful transition to secondary education and continue to develop academically, socially, and emotionally.

Chapter 3

Internalising symptoms and working memory as predictors of mathematical attainment trajectories across the primary-secondary education transition

Chapter Prologue

Chapter 3 is the first of a three-part investigation using data from ALSPAC focusing on the longitudinal predictors of maths attainment trajectories. In this chapter I examine cognitive and emotional predictors of attainment, specifically, working memory capacity and internalising symptoms, and whether these variables are associated with maths attainment at age 11, and the rate of change over time. I build upon existing research focusing on the effects of anxiety and working memory capacity on performance (Owens, Stevenson, Hadwin, & Norgate, 2012, 2014; Owens et al., 2008), by assessing whether these effects are also present for internalising symptoms and working memory. This chapter further adds to previous research by examining the longitudinal associations of these predictors with attainment, rather than the short-term effects reported in previous research.

Abstract

The transition from primary to secondary education is a critical period in early adolescence which is related to increased anxiety and stress, increased prevalence of mental health issues, and decreased maths performance, suggesting it is an important period to investigate maths attainment. Previous research has focused on anxiety and working memory as predictors of maths, without investigating any long-term effects around the education transition. This study examined working memory and internalising symptoms as predictors of children's maths attainment trajectories (age 7 - 16) across the transition to secondary education using secondary longitudinal analysis of the Avon Longitudinal Study of Parents and Children (ALSPAC). This study found statistically significant, but very weak evidence for the effect of internalising symptoms and working memory on maths attainment. Greater parental education was the strongest predictor, suggesting that children of parents with a degree (compared to those with a CSE) gain the equivalent of almost a year's schooling in maths. However, due to methodological limitations, the effects of working memory and internalising symptoms on attainment cannot be fully understood with the current study. Additional research is needed to further uncover this relationship, utilising more time-appropriate measures.

Introduction

The current state of maths attainment and performance of children and adults in the UK is particularly alarming. It is estimated that 49% of working-age adults in the UK have the maths skills expected of primary-school children, with only around 22% of working-age adults having the equivalent of a C-grade or above in GCSE maths (National Numeracy, 2018). Recent data from the 2015 Programme for International Student Assessment (PISA) suggests that numeracy levels of the UK have not changed since 2012 (OECD, 2014; OECD, 2016a), highlighting the increasing importance of investigating factors affecting the maths abilities of children and adolescents, and to intervene before any problems are allowed to extent into adulthood. The problems stemming from poor maths attainment in childhood persist well into adulthood. Underachievement in maths is related to several negative consequences, including lower socioeconomic status (SES; Ritchie & Bates, 2013) and poor employment prospects through lower rates of full-time employment, more frequent periods of unemployment, and lower rates of promotion (Parsons & Bynner, 1997). Moreover, low maths abilities have been linked to a greater likelihood of living in disadvantaged housing, experiencing homelessness, poorer health outcomes and a higher likelihood of experiencing depression (for a review see NRDC, 2013). Therefore, the ability to identify predictors of maths attainment as early as possible in childhood provides numerous advantages when attempting to increase maths attainment and improve performance. These benefits apply to both the individual at risk of poor performance, for example, through increased wealth and employment related to increased maths attainment (Geary, 2011b), and to the policy-makers implementing strategies that are *effective* in overcoming these issues.

To date, various predictors of maths attainment have been examined, mostly relating to cognitive abilities, though an increasing focus on affective factors is evident in the literature. This study aims to investigate aspects of cognitive and affective domains (and the relationship between them), by focusing on the potential associations between internalising symptoms, working memory, and maths attainment trajectories from childhood to late adolescence with a particular focus on the period around the transition from primary to secondary education.

Affective factors and maths attainment

Several affective factors such as internalising symptoms and early temperament have been associated with the development of academic and mathematical abilities, influencing both immediate performance, and long-term attainment. Internalising symptoms refer to self-directed internal distress (Tandon, Cardeli, & Luby, 2009) and include both anxious- and depressive experiences. Internalising symptoms are the most common mental health issue in childhood (Merikangas et al., 2010; Polanczyk et al., 2015), with internalising disorders (i.e. anxiety and depression) being highly comorbid (Axelson & Birmaher, 2001). Anxiety disorders are usually the first to emerge (age 6; Merikangas et al., 2010), with around 10% of pre-schoolers aged 2-5 displaying an anxiety disorder (Egger & Angold, 2006). Whereas, other internalising symptoms (including depression) typically emerge later on in early adolescence (Costello, Copeland, & Angold, 2011; Merikangas et al., 2010).

Children with increasing trajectories of internalising symptoms are more likely to experience worse academic achievement compared to their peers with fewer symptoms (Patalay, Deighton, Fonagy, & Wolpert, 2015). The relationship between internalising

symptoms and academic achievement has been found in studies investigating the effects of depression, (Fröjd et al., 2008; Ialongo, Edelsohn, & Kellam, 2001; Riglin et al., 2013; Riglin, Petrides, Frederickson, & Rice, 2014), social withdrawal from peers (Ollendick, Weist, Borden, & Greene, 1992), and anxiety (Ialongo, Edelsohn, Werthamer-Larsson, Crockett, & Kellam, 1994; Seipp, 1991). Within this literature, the focus of these studies have predominantly been general academic achievement, however, given the importance of maths skills for both children and adults, it is vital we investigate the processes influencing the development and performance of maths abilities specifically. To date, most of the research investigating affective aspects and maths attainment have focused on the role of maths anxiety (see Dowker et al., 2016 for a review). Nevertheless, the few studies that have examined the impact of general emotional symptoms have found that increased internalising problems are linked to poor maths skills in pre-school children (aged 3-5; Dobbs et al., 2006) and adolescents (aged 13-16; Marcotte, Lévesque, & Fortin, 2006), and maths anxiety in adults (aged 18; Field, Evans, Bloniewski, & Kovas, 2019) - which is closely related to maths attainment (Dowker et al., 2016). However, because the study of Dobbs et al. (2006) was cross-sectional, focusing on a limited period in early childhood, and the study of Marcotte et al. (2006) was longitudinal with relatively short follow-ups, and focused solely on the effects of depression, it is unknown whether the trajectory of maths attainment is affected long-term by emotional symptoms.

One commonly reported characteristic related to internalising symptoms is an emotional temperament in early childhood (Muris & Ollendick, 2005; Nigg, 2006). Temperament is broadly defined as an individual's character, personality, or traits that remain generally stable over time and across contexts, and is often used as a term

relating to the variation of emotional reactivity displayed early on in children and infants (Rettew & McKee, 2005). Those with a particularly ‘emotional’ temperament experience feelings of fear, anger, and sadness, and characteristics closely related to the ‘Big Five’ (Costa & McCrae, 1992) personality trait of neuroticism (Muris & Ollendick, 2005). Therefore, if increased internalising symptoms are associated with decreased maths attainment, and an emotional temperament predicts internalising symptoms, then it is plausible that an emotional temperament in childhood could be a very early indicator of poor maths attainment later on in adolescence, which this study aims to explore further. The earlier we can identify potential problems relating to attainment (i.e. by assessing childhood temperament), the earlier interventions can be administered, increasing their effectiveness.

Although there is limited empirical research within this field, we can draw upon the processing efficiency theory (PET; Eysenck & Calvo, 1992) as a framework of how internalising symptoms (specifically anxiety) might influence the performance of maths skills. The PET proposes that aspects of anxiety (i.e. worry), consume processing and working memory storage resources. The PET assumes that state anxiety is determined by trait anxiety and situational threat, meaning that those experiencing high trait anxiety (and potentially other internalising symptoms) are more likely to experience high state anxiety in response to highly stressful situations (Mathews & MacLeod, 2005). The intrusive, ruminating thoughts experienced by both anxious and depressed individuals are thought to divert valuable cognitive resources away from the task at hand (Levens, Muhtadie, & Gotlib, 2009). From these ideas, we propose that a highly trait-anxious child would experience high state anxiety when taking a maths exam or attempting maths tasks that are perceived as being stressful or ‘threatening’. Maths requires mental

operations that place a heavy load upon cognitive resources (Cragg & Gilmore, 2014) - the same resources that state anxiety is thought to consume, implying that maths is more susceptible to performance interference resulting from high trait and state anxiety compared to other subjects. Additionally, key symptoms of anxious- and depressive disorders include the inability to concentrate, loss of interest and worried/suicidal thoughts, all of which, can interfere with academic performance generally. Anxiety also influences a number of school-related factors including school refusal and school dropout (Kessler, Foster, Saunders, & Stang, 1995; Last & Strauss, 1990; Van Ameringen, Mancini, & Farvolden, 2003).

Working memory and maths attainment

One key cognitive resource that is often argued to be significant in the relationship between internalising symptoms and poor academic performance is working memory. Working memory has been referred to as a ‘mental workplace in which information can be stored and processed for brief periods of time in the course of demanding cognitive activities’ (Gathercole, Pickering, Knight, & Stegmann, 2004, p. 2). Several researchers have highlighted the importance of working memory within education (see Prince & Gifford, 2016). It has also been viewed as a better predictor of achievement than IQ (Alloway & Alloway, 2010), with several studies linking working memory to academic achievement in children (Gathercole & Pickering, 2000; St Clair-Thompson & Gathercole, 2006) and adolescents (Gathercole et al., 2004).

Working memory is particularly important for the performance of maths skills, with early measures of working memory (age 4) predicting maths achievement at age 7 (Bull et al., 2008). Working memory has been found to account for variance in a

number of mathematical skills across different age groups (see Cragg & Gilmore, 2014), even when controlling for IQ, age, and reading skills (e.g. Andersson, 2007). This is evident in cross-sectional, longitudinal, experimental, and maths disabilities studies (for a review see Raghubar et al., 2010). Additionally, working memory skills can discriminate between students of low and average abilities (Gathercole et al., 2004). Working memory has also been found to correlate with maths anxiety (Ashcraft & Kirk, 2001), with performance particularly impaired by maths anxiety on high working-memory load tasks (Ashcraft & Krause, 2007).

There is a growing literature that indicates greater internalising symptoms predict poorer working memory functioning (for a review see Moran, 2016). Internalising symptoms (anxiety & depression) are related to slower performance on working memory tasks in young children (aged between 3-7; Visu-Petra, Cheie, Benga, & Packiam Alloway, 2011; Visu-Petra, Miclea, Cheie, & Benga, 2009) and impaired performance in older children (aged between 9-11; Hadwin, Brogan, & Stevenson, 2005; Opris, Cheie, Trifan, & Visu-Petra, 2019). It is argued that working memory can explain the debilitating effect of anxiety, (and potentially depression; Levens et al., 2009; Waszczuk, Brown, Eley, & Lester, 2015) on maths tasks. Owens and colleagues found that working memory acted as a mediator between anxiety and both maths achievement (Owens et al., 2008), and general academic achievement (Owens et al., 2012) in early adolescents (aged 11-13). Further studies suggest that working memory capacity moderates the relationship between anxiety and academic performance: highly anxious individuals with high working memory capacity perform well, whereas highly anxious individuals with low working memory capacity underperform (Owens et al., 2014). However, it is unknown whether this relationship persists throughout

development, and whether this is specific to anxiety or internalising symptoms generally, given the similar symptomology and effects on cognitive resources.

The primary-secondary education transition

Research has found that emotional problems are heightened during early adolescence (Kessler et al., 2005; Merikangas et al., 2010), are frequently linked to negative outcomes including poor academic achievement (Rapport, Denney, Chung, & Hustace, 2001; Steele, Armistead, & Forehand, 2000), and increase around the time of the transition from primary to secondary education (Chung et al., 1998; Coelho & Romão, 2016; Evans, Borriello, & Field, 2018; Zeedyk et al., 2003). This transition occurs at age 11 in the UK (other countries vary but mostly transition between ages 10-14) and is often regarded as a difficult period for many children (Evans et al., 2018) that can induce considerable anxiety and stress (Chung et al., 1998; Coelho & Romão, 2016). The transition coincides with a range of developmental changes including puberty and the increased prevalence of mental health disorders (Kessler et al., 2005; Merikangas et al., 2010). In addition, the change to a different educational environment often involves one or more of the following: forming new friendship groups, new school buildings to navigate, establishing *several* new student-teacher relationships, and increasing independence from parents. These changes can all be stress-inducing: during the transition children report greater anxiety over increased workload, relationship concerns, fear of bullies and fear of getting lost (Zeedyk et al., 2003).

The transition from primary to secondary education is potentially influential in the development of maths abilities for several reasons. Firstly, the transition to secondary education is associated with declines in academic achievement generally and

interruptions of attainment growth (Akos et al., 2015; Alspaugh, 1998). Secondly, when investigating maths attainment specifically, it is reported that 34% of children do not show any progress in maths during the transitional year (Galton et al., 1999). Thirdly, several studies show decreasing enjoyment and interest in maths, less involvement in maths class, and decreasing self-efficacy and attitudes towards maths following the transition to secondary education (Barth et al., 2011; Deieso & Fraser, 2019; Eccles et al., 1984; Midgley et al., 1989a; Wilkins & Ma, 2003). Maths anxiety also increases during the transition, especially for females and high-achievers (Madjar et al., 2018b). Furthermore, decreased maths attainment growth around the transition is associated with increased maths anxiety in adulthood (Field et al., 2019). These findings combined suggest that the primary-secondary education transition is a key period to focus on when investigating predictors of maths attainment.

Overall, the literature presented suggests that the primary-secondary education transition is a stressful period in adolescence that is linked to increased anxiety, poor maths attainment, and decreased academic progress. Underachievement in maths is predicted by low working memory capacity and high anxiety, with the PET proposing that state anxiety (which is heightened in individuals with high trait anxiety) consumes working memory resources. Research to date has not investigated the effects of the education transition on maths attainment, specifically examining the role of internalising symptoms more generally, and working memory capacity on maths attainment trajectories. Empirical studies to date have predominantly focused on the effects of anxiety on maths performance, mostly ignoring other internalising symptoms that have similar symptoms and effects on attainment and cognition (e.g. depression). Moreover, the existing literature has investigated the effects of working memory and

internalising symptoms (i.e. anxiety) on attainment mostly in relatively small samples of young adolescents, with longitudinal studies often utilising short-term follow-ups. This dearth of longitudinal research means that we cannot determine how internalising symptoms and working memory influence the development and performance of maths attainment over time, and *if* this relationship remains present throughout the entirety of formal schooling, which this study aims to uncover.

The present study

This study aims to investigate the influence of an emotional temperament (measured at age 3), working memory capacity (at age 10), and internalising symptoms (at age 11) on maths attainment trajectories throughout childhood and adolescence, while investigating other potential contextual predictors including: SES, IQ, biological sex, parental education, and traumatic life events. These variables are included as possible contextual predictors based on previous research linking IQ, male sex, higher SES and greater parental education to greater educational attainment generally, and within the domain of maths (Bradley & Corwyn, 2002; Deary, Strand, Smith, & Fernandes, 2007; Dubow, Boxer, & Huesmann, 2009; OECD, 2016a). This study aims to add to the existing literature by focusing specifically on maths attainment across the transition to secondary education, which has not yet been examined. The present study utilises secondary analysis of longitudinal data from the Avon Longitudinal Study of Parents and Children (ALSPAC), examining the trajectory of maths attainment of children from age 7 up to age 16 using national curriculum assessments.

Based on previous research, it is hypothesised that a) a highly emotional temperament will predict decreased maths attainment; b) higher working memory will

be related to higher maths attainment; c) greater internalising symptoms will be related to poorer maths attainment; and d) working memory will moderate the relationship between internalising symptoms and maths attainment.

Method

Sample

The sample consists of participants from the ALSPAC cohort. ALSPAC is a large UK birth cohort of pregnant women residing in the South West of England with a due date between the 1st of April 1991 and the 31st of December 1992 (Fraser et al., 2013). Women were recruited through media campaigns and maternity health services (Boyd et al., 2013). The core sample consisted of 14,062 live births, of which 13,988 children were alive at 1 year. Additional participants were recruited resulting in a total of 15,589 fetuses, of which 14,901 were alive at 1 year. The sample is generally representative of the overall population however, there is a slight over-representation of white families with higher socioeconomic status (Boyd et al., 2013).

Data were collected using self-report postal questionnaires which were completed by the mother, the mother's partners, the study child, and the child's teacher. A smaller sub-sample (10%) were invited to attend Children in Focus clinics. The current study uses data from single-child pregnancies, and the first born of twin pregnancies. Children identified as having special educational needs (SEN) at age 7 and/or age 11, and non-English speakers were excluded prior to analysis ($n = 2,666$). It was considered that these children may face additional difficulties within education that

may influence the results of the study. Due to high rates of attrition and missing data (see analysis section), the final sample size was 8,769.

The study website contains details of all the data that is available through a fully searchable data dictionary and variable search tool (see <http://www.bristol.ac.uk/alspac/researchers/our-data/>). All participants provided written informed consent prior to the study. Ethical approval was obtained from the ALSPAC Ethics and Law Committee and the Local Research Ethics Committees. Informed consent for the use of data collected via questionnaires and clinics was obtained from participants following the recommendations of the ALSPAC Ethics and Law Committee at the time.

Measures

Maths attainment.

In England, children in formal education are assessed at ‘key stages’ up until age 16. There are 4 key stages relating to different phases of development with exams or assessments at the end of each stage to evaluate the child’s progress. For this study, maths grades at age 6-7 (key stage 1), age 10-11 (key stage 2), age 13-14 (key stage 3), and age 15-16 (key stage 4) were obtained from external education records (National Pupil Database). In key stages 1-3, children are assigned a numerical grade based on their performance ranging from 1-8, with a higher grade reflecting higher maths attainment. The expected grades of children for each key stage are level 2 at key stage 1, level 4 at key stage 2, and between levels 5-6 at key stage 3. At key stage 4, adolescents can achieve an alphabetical grade from U-A* which were coded to 2-10, with 10 being the highest grade achievable (i.e. A*). The key outcomes

of this study were maths attainment at key stage 2 (age 11), and the overall growth in maths attainment over time.

Internalising symptoms. The Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997) was used to assess children's internalising symptoms at age 11. The questionnaire assesses general mental health functioning and covers the following areas: prosocial behaviour, hyperactivity, emotional symptoms, conduct problems, and peer problems. An internalising symptoms score was calculated based on a sum of emotional symptoms and peer problems (e.g. 'I am often unhappy' and 'I am usually on my own'). Respondents rated their child's behaviour on a 3-point scale of *not true*, *somewhat true* and *certainly true*. The score ranges from 0-20 with a higher score indicating a greater number of difficulties. The SDQ has good concurrent and predictive validity (Goodman, 1997), and satisfactory internal consistency (Cronbach's α for emotional difficulties = .66, and for peer problems α = .53; Stone, Otten, Engels, Vermulst, & Janssens, 2010).

Emotional temperament. The Emotionality Activity Sociability (EAS) temperament measurement scale (Buss & Plomin, 1986) was included as it is often an early indicator of later emotional and behavioural problems (Abulizi et al., 2017), meaning it could be a way to gauge early internalising symptoms. The EAS was administered when the child was 38 months old (3.17 years) from which the emotionality scale was extracted to measure an 'emotional temperament'. This score ranges from 5 to 25 with a high score corresponding to a higher level of emotionality. Respondents rated their child's behaviour from *not at all like* to *exactly like* on a 5-point scale. Items included: 'child cries easily', 'child tends to be somewhat emotional',

‘child often fusses and cries’, ‘child gets upset easily’, and ‘child reacts intensely when upset’.

Working memory and general intelligence. IQ was assessed using the Wechsler Intelligence Scale for Children (WISC-III; Wechsler, 1991), which was administered as part of a Clinic in Focus session at age 8. Only a sub-sample (10%) of the cohort were invited to this session. The WISC IQ measure comprised of five verbal subtests (information, similarities, arithmetic, vocabulary and comprehension) and five performance subtests (picture completion, coding, picture arrangement, block design and object assembly). The short-form of each of the IQ subtests were administered to reduce the length of the session (with the exception of the coding subtest where children completed the full task). The scorings for each of the short-form subtests were then coded to be on the same scale as if the full subtest had been administered. The WISC-III shows good test-retest reliability (.80-.89; Strauss, Sherman, & Spreen, 2006).

Working memory was assessed through a computer task using the Counting Span Task (Case, Kurland, & Goldberg, 1982) in a Clinic in Focus session at age 10. The Counting Span Task involved presenting children with screens of red and blue dots, followed by asking them to point to and count the number of red dots out loud. Immediately after children counted the dots correctly, they were asked to recall the number of red dots on the screens in the order they were presented. Children were shown two practice screens followed by three sets of two screens, three sets of three screens, three sets of four screens, and three sets of five screens, totaling to 42 trials. Children were asked to attempt all the sets regardless of their performance on the set prior. The global score was used representing the number of trials/sets children

answered correctly (scored from 0-42), reflecting their processing abilities and memory storage.

Biological sex. Biological sex at birth was added in as a predictor due to potential sex differences in maths attainment. This variable was dummy coded with females being the reference group. Females accounted for 51.5% of the sample.

Socioeconomic status. Socioeconomic status was measured using the Cambridge Social Interaction and Stratification Scale (CAMSIS). The CAMSIS measures occupational structure based upon social interactions (Prandy & Lambert, 2003). Possible scores can range between 1 (least advantaged) and 99 (most advantaged) with a mean of 50 and a standard deviation of 15 in the national population (Ralston, Feng, Everington, & Dibben, 2016). The correlation of CAMSIS scores in this sample between mother and partner available at different timepoints was high (.6-.89). In addition, the data available for each timepoint decreased with each wave, therefore, to retain as much data as possible, the CAMSIS score at 32 weeks gestation was used, with the highest score available taken from either parent.

Parental education. Parental education was measured by asking the respondents of the highest qualification each parent had achieved at 32 weeks gestation. This was coded into the following six categories: no qualifications, no higher than CSE or GCSE, an O-level or equivalent, an A-level or equivalent, a teaching or nursing qualification (i.e. vocational qualifications), and a university degree. The highest qualification available was taken from either parent. Of those respondents, 9.2% had the highest qualification of a CSE (this group also included parents with no qualifications

due to small numbers), 5.5% had a vocational qualification, 26.3% had an O level, 34.3% had an A level, and 24.7% had a degree.

Traumatic life events. Traumatic life events were included to control for any events that might increase internalising symptoms or decrease maths attainment. Respondents were asked about traumatic events that have happened since the child's 5th birthday, measured when the child was 6.75 years old. This score could range from 0 to 72 and was a weighted sum of 18 items such as 'a pet died', 'the child was separated from their father' and 'the child was sexually abused'. Responses included: *yes the event happened*, and the child was: *very upset, quite upset, a little upset*, or *not upset*; or *no the event did not happen*. A high score corresponds to a higher number of events, or the child was more negatively affected by the event.

Data analysis

Exclusions and missing data. The initial cohort consisted of 13,988 children alive at 1 year. Additional recruitment resulted in 14,901 children alive at 1 year (including singletons and twins; triplets and quadruplets were excluded due to rarity). Withdrawal from the study led to a sample size of 14,684. Of this, data from singletons and the first-born twin were retained for analysis ($N = 14,498$). Fourteen children were excluded as their first, or second main language was not English ($N = 14,484$). 2,652 children reported to have special educational needs (identified by teachers at ages 7-8 and 10-11) were excluded leaving a total sample size of 11,832. Finally, 3,063 participants lacking data for around 50% of the predictor variables were excluded leaving a final sample size of 8,769 (of which 1,985 were complete cases).

The longitudinal design of the ALSPAC study resulted in high attrition rates and missing data (see Table 1 for a breakdown of missing data per variable). To overcome this multiple imputation was performed, using the *semTools* (Jorgensen, Pornprasertmanit, Schoemann, & Yves, 2018) and *Amelia* (Honaker, King, & Blackwell, 2011) packages in R (R Core Team, 2017). Due to the amount of missing data, 70 imputations were performed, and the results were pooled (White, Royston, & Wood, 2011). The outcome variables were included in the imputation model but were not imputed based on best practice (White et al., 2011). To overcome incomplete outcome data Full Information Maximum Likelihood (FIML) estimation was used. This method uses all available information to produce the maximum likelihood estimation of parameters (Acock, 2005), and has been shown to be a superior method when dealing with missing data (Enders & Bandalos, 2001).

Statistical analysis. All analyses were conducted in R version 3.4.3 (R Core Team, 2017). A latent growth model (see Figure 2) was fit predicting maths attainment trajectories over the transition using the *lavaan* package (Rosseel, 2012). Maths attainment at 7, 11, 14, and 16 years were endogenous observed variables predicted from latent variables representing the intercept and slope for growth in maths attainment over time. The loadings for the paths from the slope latent variable to the four maths attainment outcomes were constrained to be -4 , 0 , 3 and 5 so that the intercept represented maths attainment at 11 years old (i.e. the time of the school transition). The predictors specified in the measures section above were included as exogenous observed variables that predict the intercept and slope of growth in maths attainment. Predictor variables that have no meaningful zero were centred to ease interpretation (SES, IQ, working memory & emotional temperament (EAS)).

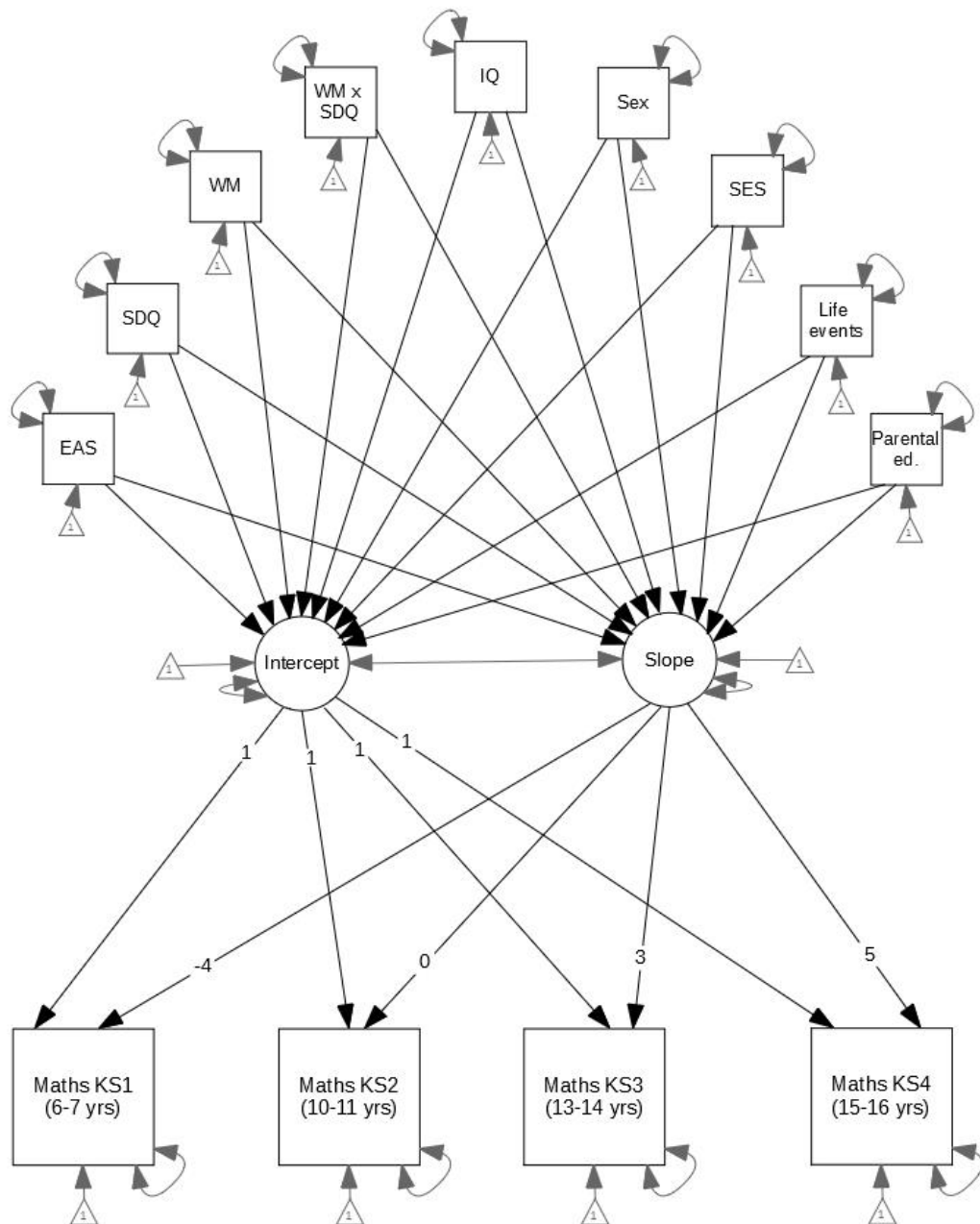


Figure 2. Latent growth model for maths attainment trajectories pre-transition to secondary education. The intercept represents maths attainment at age 11, and the slope represents maths attainment from age 7 to 16. Paths between predictor variables are implied but not illustrated. EAS = emotional temperament, SDQ = internalising symptoms, WM = working memory, ed. = education.

Emotional temperament, working memory and internalising symptoms were the substantive predictors of maths attainment in this study. Working memory has been found to moderate the effect of anxiety on cognitive task performance (Owens et al., 2014), therefore the interaction of working memory and internalising symptoms was included to test for moderation. Socioeconomic status, IQ, gender, parental education, and traumatic life events were explored as contextual predictors. When examining parental education, having the highest qualification of a CSE was used as the reference group. The latent growth model provided satisfactory fit indices, CFI = 0.942, TLI = 0.889, RMSEA = 0.108 [90% CI = 0.105, 0.112], SRMR = 0.059. All predictors were entered simultaneously.

Results

Descriptive statistics for the model predictors and outcomes are presented in Table 1. For the outcome of maths attainment, participants' grades were broadly consistent with governmental recommendations for all key stages. Children's yearly progress on average was also in-line with governmental guidelines, with children expected to progress half a national curriculum level per year (0.53 levels within this sample).

Table 1.

Summary statistics for the key study measures.

| Measure | <i>n</i> | Min | Max | <i>Mdn</i> | <i>M</i> | 95% CI | <i>s</i> | % MD |
|-------------|----------|-------|--------|------------|----------|------------------|----------|------|
| WM | 5669 | 0.00 | 42.00 | 19.00 | 19.14 | [18.95, 19.34] | 57.66 | 34% |
| SDQ | 6010 | 0.00 | 20.00 | 2.00 | 2.40 | [2.34, 2.47] | 6.61 | 30% |
| IQ | 5957 | 49.00 | 151.00 | 105.00 | 106.16 | [105.76, 106.55] | 244.18 | 30% |
| EAS | 7907 | 5.00 | 25.00 | 12.00 | 12.44 | [12.34, 12.53] | 17.40 | 7% |
| SES | 7077 | 23.72 | 99.00 | 58.18 | 58.73 | [58.46, 59.00] | 138.27 | 17% |
| Life events | 6925 | 0.00 | 33.00 | 2.00 | 2.94 | [2.86, 3.02] | 11.70 | 19% |
| KS1 Maths | 6355 | 0.00 | 3.00 | 2.00 | 2.27 | [2.25, 2.28] | 0.30 | 26% |
| KS2 Maths | 6973 | 1.00 | 6.00 | 4.00 | 4.30 | [4.28, 4.31] | 0.51 | 18% |
| KS3 Maths | 6037 | 1.00 | 8.00 | 6.00 | 6.18 | [6.15, 6.21] | 1.43 | 29% |
| KS4 Maths | 6533 | 2.00 | 10.00 | 7.00 | 7.28 | [7.24, 7.32] | 2.56 | 24% |

Note. WM = working memory, SDQ = internalising symptoms, EAS = emotionality, MD = missing data.

Predictors of the intercept (maths attainment at age 11)

Table 2 shows the model parameters for predictors of the intercept of maths attainment (i.e. at KS2, age 11). Attainment could vary from level 1 to 8 up until age 14, with most children attaining levels between 3-5 at age 11.

Out of the substantive predictors, greater working memory and fewer internalising symptoms significantly predicted higher maths attainment. For working

memory capacity, 1 additional trial of the task completed correctly equated to a 0.010 increase in maths attainment at age 11 ($p < .001$). For internalising symptoms (SDQ), a 1-unit increase in SDQ score equated to a decrease of 0.017 in attainment ($p < .001$). Working memory did not significantly moderate the effect of SDQ on maths attainment ($p = .066$). Emotional temperament was not a significant predictor of maths attainment at age 11 ($p = .956$).

Of the contextual predictors, higher IQ, higher SES, greater parental education (O level, A level & degree), and male sex were all significant predictors of greater maths attainment. The strongest predictor of attainment was parental education - when compared to parents with a CSE qualification and below, children whose parents had an O level, A level, or a degree equated to increased maths attainment at age 11 by 0.156, 0.232, and 0.412 levels respectively (all $ps < .001$). There was no significant difference in attainment for those whose parents had a vocational qualification compared to a CSE ($b = 0.020$, $p = .621$). Males maths attainment was 0.035 units higher than females at age 11. A 10-unit increase in IQ equated to a 0.19 increase in maths attainment at age 11. Traumatic life events did not significantly predict maths attainment ($b = 0.004$, $p = .085$). Overall, the effects for the significant predictors were all relatively small.

Table 2.

Model parameters for predictors of the intercept of maths attainment.

| Predictor | b | 95% CI | β | p |
|-------------------------------|--------|------------------|---------|-------|
| Working memory | 0.010 | [0.007, 0.014] | 0.106 | 0.000 |
| Internalising symptoms (SDQ) | -0.017 | [-0.023, -0.010] | -0.056 | 0.000 |
| Working memory \times SDQ | 0.001 | [-0.000, 0.002] | 0.028 | 0.066 |
| IQ | 0.019 | [0.018, 0.021] | 0.405 | 0.000 |
| Emotionality | 0.000 | [-0.004, 0.004] | -0.001 | 0.956 |
| SES | 0.005 | [0.004, 0.007] | 0.084 | 0.000 |
| Education: CSE vs. vocational | -0.020 | [-0.101, 0.061] | -0.006 | 0.621 |
| Education: CSE vs. O Level | 0.156 | [0.098, 0.214] | 0.091 | 0.000 |
| Education: CSE vs. A Level | 0.232 | [0.174, 0.289] | 0.146 | 0.000 |
| Education: CSE vs. Degree | 0.412 | [0.344, 0.479] | 0.235 | 0.000 |
| Sex | 0.035 | [0.002, 0.068] | 0.023 | 0.040 |
| Life events | -0.004 | [-0.009, 0.001] | -0.020 | 0.085 |

Note. β is the standardized parameter estimate.

Predictors of the slope (maths attainment from age 7-16)

Table 3 shows the model parameters for predictors of the slope of maths attainment from age 7 to 16. The group-level growth in maths attainment each year was 0.53, meaning that at average levels of the predictors, children progressed by around half a grade level each year.

Out of the substantive predictors, internalising symptoms ($p = .003$) and working memory ($p < .001$) were found to significantly (but weakly) predict the rate of change in maths attainment. For internalising symptoms, a 1-unit increase on the scale decreased the rate of change by 0.002. For an extra trial completed correctly on the working memory task, the rate of change in maths increased by 0.001 units. The moderation of working memory and internalising symptoms was not found to significantly predict the rate of change in maths attainment ($p = .289$). An emotional temperament was not found to predict the rate of change in attainment ($p = .892$).

The significant contextual predictors of growth in maths attainment over time were greater IQ, higher SES and greater parental education (O level, A level & degree). Compared to parents with a CSE qualification or below, children whose parents had an O level, A level, or a degree experienced increases of 0.023, 0.048, and 0.088 respectively in the rate of change of their maths attainment per year (all $ps < .001$). Children to parents with vocational qualifications did not significantly differ from children to parents with CSE qualifications ($p = .817$).

A 10-unit increase in IQ and SES increased the rate of change by 0.03 and 0.01 respectively (both $ps < .001$). Neither sex ($p = .481$) nor traumatic life events ($p = .310$) significantly predicted the rate of change in maths attainment.

It is useful to note that all these effects are relatively small within the context of a group-level rate of change of 0.53 national curriculum levels per year.

Table 3.

Model parameters for predictors of the slope of maths attainment.

| Predictor | <i>b</i> | 95% CI | β | <i>p</i> |
|-------------------------------|----------|------------------|---------|----------|
| Working memory | 0.001 | [0.001, 0.002] | 0.094 | 0.000 |
| Internalising symptoms (SDQ) | -0.002 | [-0.003, -0.001] | -0.042 | 0.003 |
| Working memory \times SDQ | 0.000 | [-0.000, 0.000] | 0.020 | 0.289 |
| IQ | 0.003 | [0.002, 0.003] | 0.339 | 0.000 |
| Emotionality | 0.000 | [-0.001, 0.001] | 0.002 | 0.892 |
| SES | 0.001 | [0.001, 0.001] | 0.096 | 0.000 |
| Education: CSE vs. vocational | 0.002 | [-0.014, 0.017] | 0.004 | 0.817 |
| Education: CSE vs. O Level | 0.023 | [0.012, 0.034] | 0.082 | 0.000 |
| Education: CSE vs. A Level | 0.048 | [0.037, 0.059] | 0.186 | 0.000 |
| Education: CSE vs. Degree | 0.088 | [0.075, 0.101] | 0.313 | 0.000 |
| Sex | 0.002 | [-0.004, 0.009] | 0.010 | 0.481 |
| Life events | -0.001 | [-0.001, 0.000] | -0.014 | 0.310 |

Note. β is the standardized parameter estimate.

Discussion

This study aimed to identify predictors of maths attainment trajectories across the primary to secondary education transition. Specifically investigating: 1) does

working memory capacity and internalising symptoms impact maths attainment pre-transition; 2) does working memory capacity and internalising symptoms influence the trajectory of maths attainment following the primary-secondary education transition; 3) are the effects of internalising symptoms on maths attainment pre- and post-transition moderated by working memory capacity, and 4) is an emotional temperament in childhood predictive of low maths attainment.

Firstly, the findings partially support the hypothesis with greater working memory ($b = 0.010$, 95% CI [.007, .014]) and fewer internalising symptoms ($b = -0.017$, 95% CI [−.023, −.010]) significantly predicting greater attainment at the time of the transition, suggesting that individuals presenting with greater emotional issues and low working memory capacity in early adolescence are more at-risk of poor performance compared to their peers around the transition. However, the effects were small suggesting that higher IQ, greater parental education, and sex (being male) are stronger predictors of higher maths attainment pre-transition. Secondly, the rate of change in maths attainment over time was significantly predicted by working memory ($b = 0.001$, 95% CI [.001, .002]) and internalising symptoms ($b = -0.002$, 95% CI [−.003, −.001]). Increased maths growth was significantly predicted by higher IQ, higher SES and greater parental education, suggesting that children with greater intelligence and higher socioeconomic status progress at a quicker rate across the transition to secondary education compared to their peers. Finally, the interaction between working memory capacity and internalising symptoms did not significantly predict pre-transition maths attainment ($b = 0.001$), or the trajectory of maths attainment over time ($b = 0.000$), suggesting overall that working memory capacity does not moderate the effects of internalising symptoms on maths attainment as hypothesised. An additional aim of this

study was to explore possible predictors of later internalising symptoms and whether these would predict attainment. It was hypothesised that an emotional temperament would predict maths attainment, given that childhood temperament and internalising symptoms are linked (Muris & Ollendick, 2005; Nigg, 2006). However, this idea was not supported (pre-transition $b = 0.000$; trajectory $b = 0.000$), suggesting that we cannot predict later problems with underattainment in maths using emotional difficulties this early on in childhood.

Internalising symptoms, working memory and maths attainment

The significant, but extremely small effects of internalising symptoms on maths attainment pre-transition, and on maths attainment growth in this study is somewhat unexpected. However, previous research has found the reported magnitude of the relationship between internalising symptoms (anxiety, depression, and other emotional issues) and attainment (both general academic and maths) is particularly broad and inconsistent where some effects range between weak to moderate (Dobbs et al., 2006; Ialongo et al., 1994, 2001; Marcotte et al., 2006; Patalay et al., 2015; Riglin et al., 2013, 2014; Seipp, 1991), and others are statistically non-significant (r between -0.1 and -0.03 ; Wu, Willcutt, Escovar, & Menon, 2014). For example, a meta-analysis by Riglin et al. (2014) found the relationship between emotional difficulties and school grades to be quite weak; $r = -0.03$, -0.10 , and -0.12 for anxiety, internalising symptoms, and depression respectively. Whereas, Ialongo et al. (2001) reports odd ratios of achieving a C grade or worse as 5.71 for males and 3.16 for females. In another study, Riglin et al. (2013) found a significant association between depressive symptoms and school grades for boys only ($\beta = -0.21$), with no significant relationship found for

girls ($\beta = -0.03$). Whereas, Dobbs et al. (2006) reports the effect size to be much more substantial when predicting maths attainment from internalising symptoms ($\beta = -0.60$). However, these findings further highlight the inconsistencies within the existing literature, due to differences in measurement, ages of participants, and the outcome investigated.

There are several practical limitations of this study that require further discussion. Firstly, the measure of internalising symptoms used in this study consisted of the 'emotional issues' and 'peer problems' subscales of the SDQ (rated by the child's carer), which was assessed when the child was 11 years old. This is important because although anxiety emerges early in childhood (~6 years; Merikangas et al., 2010), depression emerges much later (~13 years; Merikangas et al., 2010), and internalising symptoms peak around puberty (age 13-15, Costello et al., 2011), potentially suggesting that the timepoint used to measure internalising symptoms in this study may have been too early to accurately capture emotional issues. Existing research further highlights that the adolescent period (aged 11-18) is when most psychiatric disorders are diagnosed (~75%; Kim-Cohen et al., 2003), and although an early intervention is vital, it appears that assessing internalising symptoms this early (age 11) may not be effective for predicting poor maths attainment later on. The variability of internalising symptoms in this sample was also small ($M = 2.4$, $Mdn = 2.00$, & $SD = 2.6$; possible SDQ scores range from 0-20), with slightly lower scores compared to the norms for British children of a similar age (Meltzer, Gatward, Goodman, & Ford, 2000). Furthermore, the sample in the present study was more likely to be white, with higher SES whereas in previous research such as Dobbs et al. (2006) the sample consisted of mostly African-American, and Hispanic children, with low SES and parental education (both of which are linked

to greater prevalence of mental disorders; Meltzer et al., 2000). Although internalising symptoms may correlate moderately with attainment when assessed around the same time in childhood (i.e. Dobbs et al., 2006, $r = 0.29$), the effect on later attainment is either extremely small, or is simply stronger in those with less protective factors such as high SES and parental education.

Previous research has found working memory capacity is linked to better performance on maths tasks from very early childhood, through to adulthood (Andersson, 2007; Bull et al., 2008; Cragg & Gilmore, 2014; Hoard, Geary, Byrd-Craven, & Nugent, 2008; Passolunghi, Mammarella, & Altoè, 2008; Raghubar et al., 2010). However, the findings of the present study only slightly support existing research by finding a very small effect of working memory on maths attainment. One explanation is that the working memory measure used in this study was too blunt to accurately measure the components required for maths tasks. For example, several studies have investigated the predictive power of the separate components of working memory (i.e. central executive, visuo-spatial sketchpad, phonological loop & episodic buffer) on maths attainment and how each system independently accounts for variation in maths performance (e.g. DeStefano & LeFevre, 2004). Researchers have shown that children utilise different components of working memory when performing maths tasks depending on their age (Hitch, Halliday, Schaafstal, & Schraagen, 1988; Holmes & Adams, 2006; McKenzie, Bull, & Gray, 2003; Rasmussen & Bisanz, 2005), with younger children more reliant on visuo-spatial working memory than older children who tend to use more verbal strategies. The working memory measure in this study consisted of a computer task where children were asked to recall the number of dots presented which taps into visuo-spatial working memory, which explains why this

measure only weakly predicts maths attainment at age 11, as the change in strategy from visual to verbal occurs around age 10/11 (Van de Weijer-Bergsma, Kroesbergen, & Van Luit, 2015). However, as children age they start using more efficient strategies which are less reliant on working memory resources altogether, which also reduces the negative effect of high working memory load on the performance of the maths task (Imbo & Vandierendonck, 2007). Further to this, children taking maths exams in secondary education in the UK are instructed by their teachers to show their working out to questions to gain ‘method marks’, meaning that even if the final answer is incorrect, they still receive marks if their technique was otherwise accurate. It could be speculated that this encourages children to write down the information needed to calculate the answer step-by-step, meaning that they do not have to hold this information in their memory for very long, thus reducing the need for high working memory capacity to be successful in these examinations.

This change in memory strategy can also help explain why working memory capacity did not moderate the effects of internalising symptoms on maths attainment trajectories as found by previous research (Owens et al., 2012, 2014, 2008). The PET (Eysenck & Calvo, 1992) states that aspects of anxiety negatively affect performance by disrupting the use of cognitive resources (i.e. working memory). Therefore, by switching to strategies that are less susceptible to the negative effects of high working memory load, internalising symptoms are less likely to interfere with the systems required for successful problem-solving on maths tasks. However, the discrepancies in findings could also be due to differences between studies in sample size, measures of working memory and internalising symptoms, and the age these variables were measured. These inconsistencies further highlight the complexity of this relationship

and the need for additional research to understand the mechanisms involved in maths attainment.

Contextual predictors of maths attainment

There are other notable findings of this study that are worth further discussion. Firstly, as expected, IQ significantly predicted both attainment at the transition ($b = 0.019$), and the rate of growth over time ($b = 0.003$), supported by existing research (e.g. Deary et al., 2007). When interpreting this finding, it should be highlighted that the IQ measure used in this study included tests of arithmetic abilities, which could possibly explain the relatively strong association with maths attainment. However, this idea could not be investigated within this analysis as the individual subscales of the WISC were not available. Secondly, SES was found to predict maths attainment at the transition, and the trajectory over time, though this effect was small (pre-transition $b = 0.005$, trajectory $b = 0.001$). This finding is not surprising as research has consistently found links between SES and both general academic achievement (for a review see Bradley & Corwyn, 2002), and maths performance specifically (e.g. Hadden, Easterbrook, Nieuwenhuis, Fox, & Dolan, 2020). Although, this study provides additional evidence that children with higher SES progress at a very slightly quicker rate compared to their peers.

Thirdly, males were found to achieve significantly higher grades in maths at age 11, but their rate of change over time did not significantly differ from females, suggesting that males start secondary school with a slight grade advantage ($b = 0.035$). Recent data from the PISA assessments support this finding with males on average outperforming females (OECD, 2016a), whereas, Lindberg, Hyde, Petersen, and Linn

(2010) found no real gender differences in achievement, and Hyde, Fennema, and Lamon (1990) found differences depend on the age of participants and the maths domain assessed. Although, when focusing on the transition, the differences here could be explained by motivational and affective changes occurring around this period of adolescence, such as increasing maths anxiety experienced by females (Madjar et al., 2018b) and decreasing maths enjoyment (Deieso & Fraser, 2019). Given the lack of females in STEM careers (Wang & Degol, 2017), further research would be beneficial to improve females' maths performance (and attitudes towards maths) prior to the transition to ensure they start secondary education at the same level of their male peers.

The strongest predictor of maths attainment in this study was greater parental education, significantly predicting higher attainment at the transition and faster growth in maths attainment over time. Compared to children whose parents' highest qualification was a CSE, the highest attainment was for children with parents that had a degree (age 11 $b = 0.412$; trajectory $b = 0.088$), followed by those with A levels (age 11 $b = 0.232$; trajectory $b = 0.048$), then O levels (age 11 $b = 0.156$; trajectory $b = 0.023$). There was no significant difference in children's maths attainment between those with parents that had vocational qualifications compared to those with a CSE. The findings here show that children of parents who have a degree (compared to those with a CSE) gain the equivalent of close to an extra year of schooling in attainment at age 11. This finding is not unexpected, however it demonstrates the importance of parents within their child's education and suggests that having higher-educated parents may potentially 'buffer' the negative impacts of the transition to secondary education on children's attainment.

Parental support is regarded as the most important support system during the transition from primary to secondary education (Helsen et al., 2000; Waters et al., 2014). Combined with the findings of this study, this could mean that higher-educated parents support the transition in different ways that lessen the negative impact of the transition on maths attainment. However, it cannot be determined from this study which aspects resulting from greater parental education are the most important for maths attainment during this period. It could be that greater parental education generally is related to living in a ‘nice’ area, with the child attending a ‘good’ school for instance. However, given that SES was adjusted for in the model (and ultimately had a very small effect on attainment), it could be speculated that the advantage does not lie within better housing, better schools or financial resources, but instead may relate to other aspects of parenting such as attitudes towards education, involvement with school activities, or helping with homework in a supportive environment. In a review of the education transition, Rens, Haelermans, Groot, and Brink (2018) highlight the significance of parental support during this period, specifically noting the importance of parental involvement and academic encouragement, and other behaviours such as checking homework, discussing schoolwork, and monitoring their child’s social wellbeing and academic attainment. It could be that higher-educated parents are more likely to participate in these behaviours, and as such facilitate a more ‘successful’ transition. Existing research supports this link between greater parental education and more positive school involvement (e.g. Desforges & Abouchaar, 2003; Hill et al., 2004), however, the effect of these behaviours on maths attainment specifically remain unknown.

Another possible explanation for the effect of parental education on offspring attainment is the passive gene-environment correlation (passive rGE). Passive rGE refers to the phenomenon when exposure to environments depends on an individual's genotype (Plomin, DeFries, & Loehlin, 1977; Scarr & McCartney, 1983). Parents with higher education provide a more stimulating environment but also pass on genetic factors to their children that can contribute to their higher maths attainment, including traits related to increased motivation, intelligence, and temperament for example (Eccles, 2005). It has been demonstrated that both educational attainment and maths ability have strong genetic components and may co-occur due to overlapping genetic factors (Kovas et al., 2013; Shakeshaft et al., 2013). Due to this possible genetic confounding that the current study cannot rule out, additional research is needed to further understand how greater parental education leads to higher maths attainment of children, especially given the potential practical implications this may have for transition intervention strategies.

Study limitations

There are several methodological limitations of this study worth highlighting. One issue with most longitudinal analysis is that the data are now relatively old. Children's emotional, social, and educational environments are likely to be very different now compared to the individuals in the ALSPAC sample, meaning that the findings may lack some generalisability.

Another important limitation refers to the measures used within the study. Firstly, the study assumes that working memory and internalising symptoms remain stable throughout adolescence, as it was not possible to look at changes across the

transitional years and factor this into the analysis. Research has found that visual working memory continues to develop throughout adolescence (Isbell, Fukuda, Neville, & Vogel, 2015), and the stability of internalising symptoms is also questionable, with the adolescent period highlighted as a time of considerable disruption (Hannigan, Walaker, Waszczuk, McAdams, & Eley, 2017). This limitation means that any changes in the development of working memory were not accounted for. Additionally, any changes in emotional difficulties during this period in adolescence may have affected the adaptation to secondary school following the transition (Evans et al., 2018), which could have affected the participants' maths attainment also. Moreover, recent research has found that changes in internalising symptoms across this transitional period predicts increased maths anxiety in adulthood (Field et al., 2019), which is associated with maths attainment (Dowker et al., 2016). This highlights another limitation of the study, which is that a measure of maths anxiety was not available and would have been beneficial to include within the analysis.

The timing of the measures is also somewhat problematic. In previous studies, working memory and anxiety have been assessed at the same timepoint - which was not possible within this study. Instead, working memory was measured at age 10, and internalising symptoms were measured at age 11. This is a limitation because it means that the conclusions drawn from the analysis of the interaction between working memory and internalising symptoms may be inaccurate due to the delay between assessments. It could be that if working memory and internalising symptoms were measured simultaneously, the result may have shown a significant moderative effect. However, this is purely speculative and provides a suggestion for future research in this area.

There are additional generalisability issues with the ALSPAC sample that may have affected the strength of the predictors. Specifically, children enrolled in ALSPAC are more likely to achieve higher grades in national curriculum exams (at age 16), are more likely to be white, and of higher socioeconomic background compared to children not in the sample (Boyd et al., 2013). Therefore, any additional research investigating the effects of the transition should aim to investigate the effects for children with varied backgrounds to ensure validity, especially as children with higher SES tend to adapt to secondary education more successfully (see Evans et al., 2018).

Implications for transition strategies and future research directions

Several interventions have focused on improving academic attainment by increasing working memory capacity, however very few of these are effective long-term in increasing attainment (e.g. Colmar & Double, 2017; Melby-Lervåg & Hulme, 2013). It appears that focusing on other aspects related to attainment might be more suitable. Although not the main aim of this study, the findings imply that strategies focusing on improving parental education (or related factors) for example might be more successful in increasing attainment. Although one possible solution could be to provide better provisions for parents to attain higher educational qualifications, this is not necessarily practical (or desirable) for every family. Furthermore, it has not been determined by this study alone *how* greater parental education leads to greater attainment - first we must understand the underlying mechanisms linking parental education to better maths attainment before intervention strategies can be proposed and evaluated.

Existing research investigating factors linked to parental education has found that that greater parental education is associated with greater school involvement

(McQuiggan & Megra, 2017), greater enrolment in educational activities (e.g. music lessons) and higher educational aspirations for their child (Eccles, 2005). To date, few researchers have reviewed the effects of parental interventions focusing on these factors on attainment and have reported mixed results. Gorard and See (2013) found that interventions aiming to increase parental involvement were somewhat promising during pre-school/early primary education and were ineffective at later stages of schooling. Whereas, another review found that interventions are more beneficial for older children (Higgins & Katsipataki, 2015). A report by Ofsted (2009) investigating family learning found that interventions provided by adult and community learning hubs in the UK (in schools, Sure Start Children's Centres, and libraries) were successful in helping parents gain further educational qualifications, promoting greater parental involvement in school, and gaining paid employment. However, these programmes are not available beyond key stage 2 (i.e. post-secondary-education transition), meaning it is difficult to say how these programmes would have affected maths performance if they were offered following the transition to secondary education. Furthermore, since Ofsted's review, it is estimated that over 1,000 children's centres have been closed (Smith, Sylva, Smith, Sammons, & Omonigho, 2018), with no official figures on the closures of libraries, meaning there are fewer opportunities to encourage parents to participate in these activities, potentially resulting in a wider achievement gap between the children of parents with high- and low-education.

Although, as discussed previously, it cannot be determined from this study *how* greater parental education is linked to greater offspring attainment, especially so given the possible genetic confounding as highlighted above. Therefore, future research should focus first on what aspects relating to parental education are the most important

for maths attainment during the transitional period, taking genetic components into account.

Conclusion

To summarise, this study shows that although internalising symptoms and low working memory capacity influences maths attainment at the secondary education transition, and the growth in attainment over time, these effects are extremely weak at best. Instead, the findings here provide further evidence that low SES and low parental education are two of the biggest risk factors for low attainment in maths prior to the school transition and continue to affect the rate children progress in secondary education. Additional research is needed to further understand the effect of parental education on maths attainment in adolescents before and after the transition to secondary education to better inform policies and interventions. Recent campaigns launched by the BBC have focused on promoting adult education and maths training in collaboration with the National Numeracy Charity, and while this is a step in the right direction, much more work is needed to overcome the extent of poor numeracy in the UK and the negative effects associated with underachievement in maths.

Chapter 4

Predictors of mathematical attainment trajectories across the primary-to-secondary education transition: parental factors and the home environment

Chapter Prologue

Chapter 4 follows on from one of the key findings in Chapter 3, that parental educational qualifications were the strongest predictor of maths attainment trajectories. While this association is not surprising, the size of the effect demonstrates that the difference between children with the highest educated parents and children with the lowest educated parents is substantial, and is comparable to the equivalent of the average progress children make in one year. This chapter aims to further understand this association by examining parental and home factors that might potentially influence maths attainment trajectories using analysis of the ALSPAC cohort. In this study I focus on early home teaching, parental mental health, parent–child home interactions, parent–child relationships, school involvement, child gendered play, and parental education qualifications, and assess whether these factors are associated with maths attainment at age 11, and the rate of change over time.

Abstract

A ‘maths crisis’ has been identified in the UK, with many adults and adolescents underachieving in maths and numeracy. This poor performance is likely to develop from deficits in maths already present in childhood. Potential predictors of maths attainment trajectories throughout childhood and adolescence relate to the home-environment and aspects of parenting including parent-child relationships, parental mental health, school involvement, home-teaching, parental education, and gendered play at home. This study examined the aforementioned factors as predictors of children’s maths attainment trajectories (age 7 - 16) across the challenging transition to secondary education. A secondary longitudinal analysis of the Avon Longitudinal Study of Parents and Children (ALSPAC) found support for parental education qualifications, a harmonious parent-child relationship, and school involvement at age 11 as substantial predictors of maths attainment trajectories across the transition to secondary education. These findings highlight the importance of parental involvement for maths attainment throughout primary and secondary education.

Introduction

Carey et al. (2019) propose a ‘maths crisis’ in the UK, with a staggeringly high proportion of adults underperforming in maths and numeracy. Recent statistics show that around half of working-age adults in the UK have maths skills no better than 6-year-old children, and only 22% have the skills expected of an ‘average’ 16-year-old - a 4% decrease from 8 years prior; suggesting that the problem is getting worse (National Numeracy, 2018). In support of this decline, figures from the Programme for International Student Assessment (PISA) show that the performance of the UK has not improved since 2012 (OECD, 2014; OECD, 2016a). Low levels of mathematical and numerical skills are detrimental to individuals and to wider society. For individuals, low maths attainment is associated with greater unemployment and poor career prospects, increased mental and physical health issues, a higher likelihood of homelessness and lower socioeconomic status (Geary, 2011b; NRDC, 2013; Parsons & Bynner, 1997; Ritchie & Bates, 2013). At societal levels, poor numeracy is reported to cost £2.4 billion a year through expenses such as unemployment benefits, lost tax revenue and increased contact with the criminal justice system (Every Child a Chance Trust, 2009).

The deficits in maths and numeracy seen in adults in the UK, are likely to stem from difficulties with maths in childhood. Therefore, understanding the factors that predict maths attainment in childhood is important to inform educational practices. In response to the paucity of research investigating long-term influences on maths attainment, this study aims to identify early predictors of maths attainment in childhood and adolescence, focusing specifically on both the impact of parents, and the challenging transition from primary to secondary education.

How do parents contribute to maths cognition and learning?

Children's first educators are their parents. The early experiences parents provide for their children lay the foundations for what follows in formal schooling by developing skills and promoting the desire for the acquisition of knowledge. Parents play an extremely important role within their child's educational success with both positive and negative effects. We know that adversities present as early as pregnancy and negative experiences within the first few months of life can affect the development of cognitive abilities, negatively affecting the trajectory of educational attainment long-term. For example, smoking and drug misuse during pregnancy, other adverse childhood experiences (ACEs; i.e. domestic violence, child abuse and neglect), and poor parental mental health and wellbeing are linked to decreased cognitive development and academic abilities (Hay et al., 2001; Jimenez, Wade, Lin, Morrow, & Reichman, 2016; Lambe, Hultman, Torrång, MacCabe, & Cnattingius, 2006; Mensah & Kiernan, 2010; Ross, Graham, Money, & Stanwood, 2015; Wehby, Prater, McCarthy, Castilla, & Murray, 2011).

There is also the opportunity for positive experiences for growth and development in childhood that are provided by parents. Greater participation in educational activities at home and in school is related to increased cognitive abilities and greater educational motivation, engagement, and success (Barger, Kim, Kuncel, & Pomerantz, 2019; Department for Children, Schools and Families, 2008; Fan & Chen, 2001; Jaynes, 2007). Parents also contribute to developing early maths skills, the transmission of attitudes to, interest in, and the value given to maths, and influence their child's involvement in educational activities (at home and in school). One of the

strongest predictors of maths attainment in later childhood are the very early skills children have when starting school (Claessens & Engel, 2013; Duncan et al., 2007; Jordan, Kaplan, Locuniak, & Ramineni, 2007; Jordan, Kaplan, Ramineni, & Locuniak, 2009). Parents who provide greater opportunities for teaching maths and numbers at home significantly increase their child's future maths skills and achievement (Blevins-Knabe & Musun-Miller, 1996; Huntsinger, Jose, & Luo, 2016; LeFevre et al., 2009; Manolitsis, Georgiou, & Tziraki, 2013; Skwarchuk, Sowinski, & LeFevre, 2014). Moreover, early numeracy teaching is not *only* associated with maths outcomes, but is also correlated with increased vocabulary, more so than literacy activities (Napoli & Purpura, 2018).

The contribution of parents to their child's maths attainment does not cease with the start of school. Several researchers report parental influence on aspects of maths throughout childhood and adolescence. Cai (2003) found that greater parental involvement in primary education was associated with higher school grades. Moreover, in several studies, parents have been found to transmit maths anxiety, attitudes towards and interest in maths (Frenzel, Goetz, Pekrun, & Watt, 2010; Gunderson et al., 2012; Jacobs & Bleeker, 2004; Maloney, Ramirez, Gunderson, Levine, & Beilock, 2015), all of which are associated with maths attainment (Chen et al., 2018; Dowker et al., 2019, 2016).

Parents additionally guide their children's interests and the types of play they participate in by purchasing toys and encouraging (or discouraging) different types of activities and behaviours. One specific area of interest particularly for maths attainment is gender-stereotyped play in childhood. Typically, "boy toys" include construction toys

(such as building blocks and tools), vehicles and sports, and “girl toys” include dolls, household toys (i.e. tea sets and toy kitchens), and ‘dress-up’ (Blakemore & Centers, 2005). This divide is particularly interesting given reported differences in maths attainment between males and females (OECD, 2016a), which could potentially stem from the differences in toys and play through the increased spatial content in ‘masculine’ toys for example. Because parents heavily shape their child’s preferences and activities, examining gender-stereotyped play in childhood could help understand differences in attainment for males and females stemming from parents and aspects of the home environment.

It is evident that parents play a pivotal role within achievement which is particularly relevant in early- and middle-childhood (Desforjes & Abouchaar, 2003). Adolescence presents additional challenges that affects the acquisition of maths skills generally. Research suggests that the shift from childhood to adolescence can be a critical period for several reasons, some of which relate to the effects associated with the transition to secondary education, as now discussed.

The transition from primary to secondary education

The transition to secondary education usually occurs between ages 10-14, where young adolescents move from a typically small primary school, to a much larger secondary education institution. The transition is the norm for most students in Western societies (e.g. UK, Europe, USA, Australia and New Zealand), and is regarded as one of the most stress-inducing events young adolescents will encounter within their development and education (Chung et al., 1998; Coelho & Romão, 2016). The transition to secondary education elicits several changes within a child’s social and educational

environment. Secondary education schools are typically much larger than primary schools, with several specialised subject teachers (compared to just one teacher per school year in primary education). The transition usually involves the loss and renegotiation of friendships (Cantin & Boivin, 2004). Relationships with parents also change with the transition, with parents granting more autonomy and independence to their children as they grow into adolescents. Moreover, the transition occurs alongside the onset of puberty, and so coincides with further biological, emotional, and social changes.

The transition can have negative psychological consequences (Evans et al., 2018) including: increased anxiety (Benner & Graham, 2009), relationship concerns (Zeedyk et al., 2003), increased loneliness (Benner & Graham, 2009), fear of victimisation (Zeedyk et al., 2003), and fear of being lost or late for class (Akos & Galassi, 2004; Zeedyk et al., 2003). Individuals reporting greater concerns regarding the transition experience increased anxiety both pre- and post-transition also (Rice et al., 2011). Many of the concerns reported by parents and children are related to practical or relational issues (i.e. making friends and getting to class on-time, Akos & Galassi, 2004). However, research shows that academic achievement is also negatively impacted by the transition with declines in achievement and a lack of progress made across the transitional year (Akos et al., 2015; Alspaugh, 1998; Serbin et al., 2013).

Effects of the education transition on maths outcomes. The transition to secondary education influences the acquisition and performance of maths skills and abilities. It has been reported that 34% of children fail to make any progress in maths during the transition year (Galton et al., 1999), while other researchers have found that

maths anxiety increases (Madjar et al., 2018b). Furthermore, enjoyment and interest in maths decreases across the transition, with children becoming less involved in maths class (Deieso & Fraser, 2019), and their attitudes towards maths become more negative in secondary education (Deieso & Fraser, 2019; Wilkins & Ma, 2003). Additionally, poor maths attainment across the transition predicts greater maths anxiety at age 18 (Field et al., 2019), suggesting that this is a critical period to focus on when aiming to improve maths education outcomes. However, additional research within this area is needed to further understand the mechanisms contributing to low maths attainment.

Parental effects and the transition to secondary education. As

previously highlighted, the transition to secondary education is a turbulent time associated with negative emotional and maths outcomes. A well-adapted transition is dependent on several interacting risk and protecting factors (Evans et al., 2018), with some of the most relevant factors relating to parent-child interactions, familial support, and the home-environment.

Parental support is reportedly one of the most important support systems children have when transitioning to secondary education (Helsen et al., 2000; Newman, Newman, Griffen, O'Connor, & Spas, 2007; Rens et al., 2018), and can affect the success of the transition process in several ways. For example, greater parental presence at home has been found to be protective against a difficult transition (Waters et al., 2014). Moreover, low parental support is strongly related to greater emotional problems experienced by adolescents, with high support being an especially protective factor found during early adolescence (Helsen et al., 2000). Though generally, perceived parental support is found to decline significantly during this period (Helsen et al., 2000).

Children's attachment to their mother also predicts worries about the transition (related to academic and teacher domains), through anxiety symptoms, meaning that a secure mother-child attachment is protective against intrusive concerns and anxieties surrounding the transition (Duchesne et al., 2009). Moreover, increased autonomy support provided by parents (i.e. greater independence) prior to the transition predicted a decline in depression post-transition (Duineveld et al., 2017). Though many of these aspects relate to 'emotional support', previous studies have found that children with fewer family 'resources' (such as low SES and parental education), have worse academic (Serbin et al., 2013) and maths (Evans et al., 2020) performance across the transition, and that this may be explained by decreased parental support (Serbin et al., 2013). However, it is currently unknown how these parental factors might affect maths attainment trajectories across the transition.

The present study

To summarise, it is apparent that parents are influential for the development of maths skills and play an important role for a successful transition to secondary education. Moreover, the transition itself is associated with negative maths outcomes, raising the question of how parental factors might affect maths attainment trajectories across the transition to secondary education. Understanding which factors in childhood have negative impacts on the trajectory of maths attainment will help enable strategies for mitigating the difficulties many adults have with mathematics. There is a paucity of longitudinal research investigating maths attainment across the transition to secondary education, which as discussed previously, is a critical time for maths interest and attitudes, maths achievement, and maths anxiety. Given that parents themselves are *at*

least partly involved in the development of maths skills and the transmission of maths attitudes generally, and that parental support can buffer negative effects surrounding the primary-secondary education transition, it seems logical to investigate how parents might affect maths attainment across this transition.

Therefore, by utilising secondary analysis of the Avon Longitudinal Study of Parents and Children (ALSPAC), this study aims to investigate parental influences in childhood and early adolescence as predictors of maths attainment trajectories for typically-developing children across the transition from primary to secondary education. ALSPAC is a large UK birth cohort following children and their parents from pregnancy up to the present day and covers a broad range of measures. Previous work investigating home and parental factors using the ALSPAC cohort have focused particularly on the impact of mothers and have shown that that maths attainment is associated with maternal perinatal and postnatal mental health (Netsi et al., 2018; Pearson et al., 2016), and maternal prenatal locus of control (Golding et al., 2019). Parental education qualifications at birth are also linked to maths attainment in the ALSPAC sample (Evans et al., 2020), though, mothers' participation in adult learning was not found to improve maths grades (Sabates, Duckworth, & Feinstein, 2011). The current study aims to add to this existing literature by focusing on the influence of the home environment and parental factors on the trajectory of children's maths attainment (measured from age 7 up to age 16 using national curriculum assessments). This study looks at several indicators of the home environment and parental factors including early home teaching, parental mental health, parent-child home interactions, parent-child relationships, school involvement, parental education qualifications, and child gendered play. The analysis includes contextual variables (socioeconomic status, child IQ and

biological sex) and measures of working memory and internalising symptoms which were found to predict maths attainment in this sample by a previous study (Evans et al., 2020).

Based on existing research, it is predicted that greater involvement (i.e. home interactions, home-teaching and in school), positive parent-child relationships, greater parental education qualifications, and male-gendered play will be positively associated with maths attainment at the transition, and the growth in attainment over time. It is predicted that increased parental mental health issues will negatively impact attainment at the transition and predict a decreased rate of growth over time.

Method

Sample

This paper describes a secondary analysis of data from the Avon Longitudinal Study of Parents and Children (ALSPAC). ALSPAC is a large birth cohort consisting of children born to women residing in the South West of England with a due date between the 1st of April 1991 and the 31st of December 1992 (Boyd et al., 2013; Fraser et al., 2013). The children and their parents have been followed up extensively from pregnancy through to the present day. The core ALSPAC sample recruited initially consisted of 14,062 live births, of which 13,988 children were alive at 1 year. Additional participants were recruited resulting in a total of 15,589 fetuses, of which 14,901 were alive at 1 year. There is a slight over-representation of white families with higher socioeconomic status (Boyd et al., 2013), but generally the sample is representative of the overall population.

The data consisted of self-report postal questionnaires, completed by the study child, the child's mother/father/carer, the child's teacher(s), and the mother's partner. This study also utilises education-linked data from the National Pupil Database (NPD). Some of the data were collected through 'Children in Focus' clinics, which were attended by a smaller sub-sample (10%) of participants. Analysis was conducted on singletons and the first-born twin. The final sample size was 7,465 (see exclusions and missing data section for details).

The ALSPAC website has a fully searchable data dictionary and variable search tool (see <http://www.bristol.ac.uk/alspac/researchers/our-data/>). All participants provided written informed consent prior to the study. Ethical approval was obtained from the ALSPAC Ethics and Law Committee and the Local Research Ethics Committees. Informed consent for the use of data collected via questionnaires and clinics was obtained from participants following the recommendations of the ALSPAC Ethics and Law Committee at the time.

Outcome

Maths attainment.

In England, children in formal education are assessed at 'key stages' up until age 16. There are 4 key stages relating to different phases of development with exams or assessments at the end of each stage to evaluate the child's progress. For this study, maths grades at age 6-7 (key stage 1), age 10-11 (key stage 2), age 13-14 (key stage 3), and age 15-16 (key stage 4) were obtained from external education records (National Pupil Database). In key stages 1-3, children are assigned a numerical grade based on their performance ranging from 1-8 with a higher score indicating a better grade. The grades children are expected to attain at each of these key

stages is as follows: level 2 at key stage 1, level 4 at key stage 2, and levels 5-6 at key stage 3. At key stage 4, adolescents can achieve an alphabetical grade from the highest of 'A*', through 'A', 'B', 'C', 'D', 'E', 'F', 'G', and the lowest grade of a 'U', which were coded into numbers between 2-10, with 10 being the highest grade achievable (i.e. A*). Maths attainment at age 10-11 (key stage 2) just prior to the transition to secondary education, and the growth in attainment over time were the main outcomes of this study.

Predictors: parent and child

It is important to highlight that measures regarding the child's 'parent(s)', refer to the child's primary caregiver. Data on the specific demographics are not available for this dataset, but from the entire ALSPAC sample, this mostly consists of the child's biological mother and father, and also includes non-biological parents (i.e. step/adoptive), grandparents, and other legal guardians. For simplicity, the term 'parent' is used throughout, and refers to any of the aforementioned caregivers, unless otherwise specified.

Post-natal parental mental health. Parental mental health was assessed using the Crown-Crisp Experiential Index (CCEI, Crown & Crisp, 1979) total score, and the Edinburgh Post-Natal Depression (EPDS, Cox, Holden, & Sagovsky, 1987) score. The CCEI used in ALSPAC includes 23 items relating to somatic, depressive, and anxious symptoms with a possible score ranging between 0 and 46, with a higher score indicating more symptoms. The EPDS is mostly used to assess post-natal depression but can also be used to indicate depression in those that have not recently given birth (Cox, Chapman, Murray, & Jones, 1996). Possible scores on the EPDS

range from 0 to 30 with a higher score indicative of greater symptoms. The CCEI was administered at 8 weeks post-birth and 21 months post-birth, and the EPDS was administered at 8 weeks post-birth. The highest available score for either parent was taken from the CCEI at time 1, time 2, and the EPDS separately, meaning that the score could be from either parent for the three measures. An exploratory factor analysis (using parallel analysis) revealed one common factor (Cronbach's $\alpha = 0.81$), so a composite score was created by extracting factor scores, calculated using the regression method.

Parental interactions at home. Parent-child home interactions were measured at age 3.5 years and age 6.75 years. At age 3.5, 'mothers' (i.e. the primary female caregiver) were asked to indicate whether they, and their partner, participated in the following activities: 'bathes child', 'feeds child', 'sings to child', 'reads stories/shows pictures', 'plays with child with toys', 'cuddles child', 'plays imitation games (peek-a-boo)', 'physically plays with child' and 'takes child for walks'. Responses included: *never, less than once a week, 1-2 times a week, 3-5 times a week* and *daily* (coded as 0-4).

At age 6.75, mothers were asked if they, and their partner, participated in the following activities: 'bathes child', 'makes things with child', 'sings to child', 'reads to or with child', 'plays with child with toys', 'cuddles child', 'does active play (ball games, hide and seek)', 'takes child to park/playground', 'puts child to bed', 'takes child swimming', 'fishing, or similar activity', 'paints or draws with child', 'prepares food for child', 'takes child to classes', 'takes child shopping', 'takes child to watch sports/football', 'does homework with child', 'has conversations with child', 'helps child prepare stuff for school', and 'does other activity with child'. Responses included:

never, less than once a week, once a week, 2-5 times a week, and daily, scored from 0 (*never*) to 4 (*daily*).

The two measures had a different number of items so the score for the second timepoint was transformed to be on the same scale as the first timepoint. Factor analysis revealed two factors (determined by parallel analysis) relating to mother's interactions and partner's interactions separately, so the scores for each parent were then averaged to get a composite score for mother's interaction (for time 1 and time 2), and partner's interaction (for time 1 and time 2). Demographic data for the mother's partner is not available from this specific dataset, however, broadly across the entire ALSPAC dataset, very few mothers had female partners (time 1: 0.2%; time 2: 0.1%), relatively few were without a partner, or not living with a partner (time 1: 7%; time 2: 10.8%), and the majority had male partners (time 1: 91.9%; time 2: 86.3%). Possible scores ranged from 0 to 36 with a higher score equating to a greater parent-child interaction.

Early home teaching. Parents were asked to indicate if they taught their child the alphabet, colours, numbers and shapes at 18 months old. Polychoric factor analysis (using parallel analysis) revealed two factors which were split into verbal and numerical skills which are referred to as 'literacy' (teaching alphabet and colours), and 'numeracy' (teaching numbers and shapes) home teaching throughout. Possible scores for each measure could range from 0 (not taught any skills) to 2 (taught both alphabet and colors, *or* numbers and shapes).

Parental education. Parental education was measured by asking parents their highest qualification at 32 weeks gestation. This response was coded into the following five categories: 'no qualifications/no higher than CSE or GCSE', 'vocational

qualifications (i.e. teaching or nursing qualifications)', 'O-level or equivalent', 'A-level or equivalent', and 'university degree'. The highest qualification of either parent was used in analysis. Frequencies for each category are as follows: 8.0% had a CSE or below, 5.3% had a vocational qualification, 26.1% had an O level, 34.8% had an A level, and 25.9% had a degree. Having the highest qualification of a CSE (or below) was used as the reference group as this was the lowest level of parental education qualifications available.

Gender-stereotyped play and behaviour. Gendered play was included as an indicator of the types of toys parents provided and the play they participated in with their children at home. The Pre-school Activities Inventory (PSAI; Golombok and Rust (1993)) was used to examine the child's gender-stereotyped play. At 3.5 years, parents were asked to state how often their child plays with the following: 'guns (or similar)', 'jewellery', 'tool set', 'dolls', 'cars/planes/trains', 'swords (or similar)', 'tea set', 'played house (i.e. cleaning/cooking)', 'played with girls', 'pretended to be a female character (i.e. a princess)', 'pretended to be a male character (i.e. a soldier)', 'played fighting', 'played at being a mother/father', 'ball games', 'climbed (tree, fence, climbing frame)', 'played at looking after babies', 'showed interest in real cars/planes/trains', 'dressed up in female clothing', 'explored new surroundings', 'rough and tumble play', 'showed interest in insects/spiders/snakes', 'avoided getting dirty' and 'avoided' taking risks. Parents responded on a 5-point scale: *never*, *hardly ever*, *sometimes*, *often*, and *very often* (scored from 1-5). The items are then scored in a way that a high score on the PSAI indicates more 'masculine' behaviour.

At 8 years old, children participated in the Children's Activities Inventory (CAI; Golombok and Rust (1993); Golombok et al. (2008)), which is a shorter version of the PSAI for older children. Children were asked to indicate how much agreement they have when asked if they play with the following toys: 'jewellery', 'computer games', 'dolls', 'tea sets', 'guns', 'house (cooking and cleaning)', 'playing with boys', 'pretending to be a female character', 'fighting', 'sports', 'climbing', 'taking care of babies', 'dressing up in female clothing', 'being outdoors', 'wrestling', and 'liking pretty things', on a scale of *yes, definitely like me*, *yes, a bit like me*, *no, not really like me*, and *no, not at all like me* (scored from 1-4). As with the PSAI, the individual items were transformed so that a high score indicated more 'masculine' behaviour.

Parental school involvement. Parental involvement with school activities was assessed at age 8 and age 11. The child's school teacher was asked to indicate whether the child's parent(s) had been involved in the following activities by answering *yes* (coded as 1) or *no* (coded as 0) to: 'helping in class', 'helping with out of class activities', 'attending parent-teacher sessions', and 'being involved in another school activity'. Polychoric factor analysis and parallel analysis revealed two factors for age 8 school involvement and age 11 school involvement separately (Cronbach's $\alpha = 0.61$ & 0.62 respectively). The items were summed to create a score between 0-4 for school involvement at age 8 and age 11, with a higher score indicative of participation in more activities.

Parent-child relationships. The quality of parent-child relationships at 12.5 years were assessed using the Assessment of Mother-Child-Interaction with the Etch-a-Sketch (AMCIES; Wolke, Rios, & Unzer, 1995; Schneider et al., 2009). This

task involves the observation of a parent-child dyad during a play situation with an Etch-a-Sketch toy. Parent-child pairs were asked to draw a picture of a house, with one individual responsible for drawing horizontal lines, and the other responsible for the vertical lines - meaning they have to work closely together in cooperation.

The ALSPAC team rated the observed interaction for ‘harmony’ and ‘control’. Harmony was evaluated by assessing the amount of conflict within the interaction on a 5-point scale: ‘many conflicts’, ‘some conflicts (generally negative with some conflict)’, ‘neutral (atmosphere is neither positive or negative)’, ‘quite agreeable (generally positive)’, and ‘very agreeable (very positive and harmonious)’. Scores can range from 0 to 4, with a higher score referring to greater harmony. Control was rated by assessing whether the child or adult was in control of the session itself and who was determining the outcome of the interaction. Control was rated on a 5-point scale: ‘child is in complete control (initiates and/or directs adult)’, ‘child has most control’, ‘equal control’, ‘adult has most control’, and ‘adult is in complete control (i.e. initiates and/or directs child)’. This variable was recoded so that a high score indicated the child had the highest control (on a scale from 0 to 4).

Predictors: contextual

Biological sex.

Biological sex at birth was added in as a predictor due to potential sex differences in maths attainment. This variable was dummy coded with females being the reference group. Females accounted for 51.9% of the sample.

Socioeconomic status.

Socioeconomic status was measured using the Cambridge Social Interaction and Stratification Scale (CAMSIS). The CAMSIS measures occupational structure based upon social interactions (Prandy & Lambert,

2003) with possible scores ranging between 1 (least advantaged) and 99 (most advantaged), with a mean of 50 and a standard deviation of 15 in the national population (Ralston et al., 2016). To retain as much data as possible, the CAMSIS score at 32 weeks gestation was used, with the highest score taken from either parent.

Internalising symptoms (SDQ). The Strengths and Difficulties

Questionnaire (SDQ; Goodman, 1997) was used to measure internalising symptoms experienced by the child at age 11. The SDQ assesses emotional symptoms, conduct problems, peer problems, prosocial behaviour and hyperactivity. The sum of emotional symptoms and peer problems (10 items in total) was used as an ‘internalising symptoms’ score. Example statements of these scales include ‘I am often unhappy’ and ‘I am usually on my own’. Parents rated their child’s behaviour on a 3-point scale of *not true* (coded as 0), *somewhat true* (coded as 1) and *certainly true* (coded as 2). The internalising symptoms score ranges from 0-20 with a higher score indicating more symptoms. The SDQ has good concurrent and predictive validity (Goodman, 1997), and satisfactory internal consistency (Cronbach’s α for emotional difficulties = .66, and for peer problems α = .53; Stone et al., 2010).

Working memory and general intelligence. IQ at age 8 was measured

using the Wechsler Intelligence Scale for Children (WISC-III; Wechsler, 1991), as part of one of the Clinic in Focus sessions. The IQ measure includes short-form tasks assessing five verbal subtests (information, similarities, arithmetic, vocabulary and comprehension) and five performance subtests (picture completion, coding (full-form test administered), picture arrangement, block design and object assembly). The scorings for the short-form subtests were transformed to be as though the full-form

version of the tests had been administered. The test-retest reliability of the WISC-III is good (.80-.89; Strauss et al., 2006).

Working memory was measured using the Counting Span Task (Case et al., 1982) in the age 10 Clinic in Focus session. Displays of red- and blue-coloured dots were presented on a computer screen, and children were asked to count the number of red dots out loud, followed by recalling the number of red dots in the order they were presented for multiple screens. Children were shown two practice screens followed by three sets of two screens, three sets of three screens, three sets of four screens and three sets of five screens. Children were asked to complete 42 trials in total, reflecting the maximum score children could attain for this measure (scored from 0-42).

Data analysis

Exclusions and missing data.

The initial sample was 14,901 (see sample characteristics). Withdrawal from the study led to a sample size of 14,684. Of this, data from singletons and the first-born twin were retained for analysis ($N = 14,498$). Fourteen children were excluded as their first, or second main language was not English ($N = 14,484$). 2,652 children identified by teachers (at ages 7-8 and 10-11) as having or have had special educational needs (such as learning difficulties, emotional and behavioural difficulties, physical disabilities and speech and language difficulties) were excluded ($N = 11,832$) due to the high heterogeneity within this group. Finally, 4,367 participants lacking data for 50% or more of the predictor variables were excluded, leaving a final sample size of 7,465 (none of which were complete cases when including outcome variables).

To address the issue of high attrition rates and missing data (for missing data per variable see Table 4), multiple imputation was performed in R (R Core Team, 2017) using the *semTools* (Jorgensen et al., 2018) and *Amelia* packages (Honaker et al., 2011). Eighty imputations were performed, and the results were pooled (White et al., 2011). The outcome variables (maths attainment KS1-KS4) were included in the imputation model but were not imputed. Instead, to address the missing outcome data, Full Information Maximum Likelihood (FIML) estimation was used, which has been shown to be a superior method when dealing with missing data (Enders & Bandalos, 2001).

Statistical analysis. All analyses were conducted using R version 3.4.3 (R Core Team, 2017) and the following packages: *lavaan* (Rosseel, 2012), *psych* (Revelle, 2019), *polycor* (Fox, 2019), *nFactors* (Raiche & Magis, 2020), *tidyverse* (Wickham, 2017), *mice* (van Buuren & Groothuis-Oudshoorn, 2011), *semTools* (Jorgensen et al., 2018) and *Amelia* (Honaker et al., 2011). The *lavaan* package (Rosseel, 2012) was used to fit a latent growth model predicting maths attainment trajectories across the transition to secondary education (see Figure 3). The unconditional growth model was the same as Evans et al. (2020, p. 7), which they described as: ‘maths attainment at 7, 11, 14, and 16 years were endogenous observed variables predicted from latent variables representing the intercept and slope for growth in maths attainment over time. The loadings for the paths from the slope latent variable to the four maths attainment outcomes were constrained to be -4 , 0 , 3 and 5 so that the intercept represented maths attainment at 11 years old (i.e. the time of the school transition)’. The predictors were included as exogenous observed variables that predict the intercept and slope (i.e. the rate of change) of growth in maths attainment.

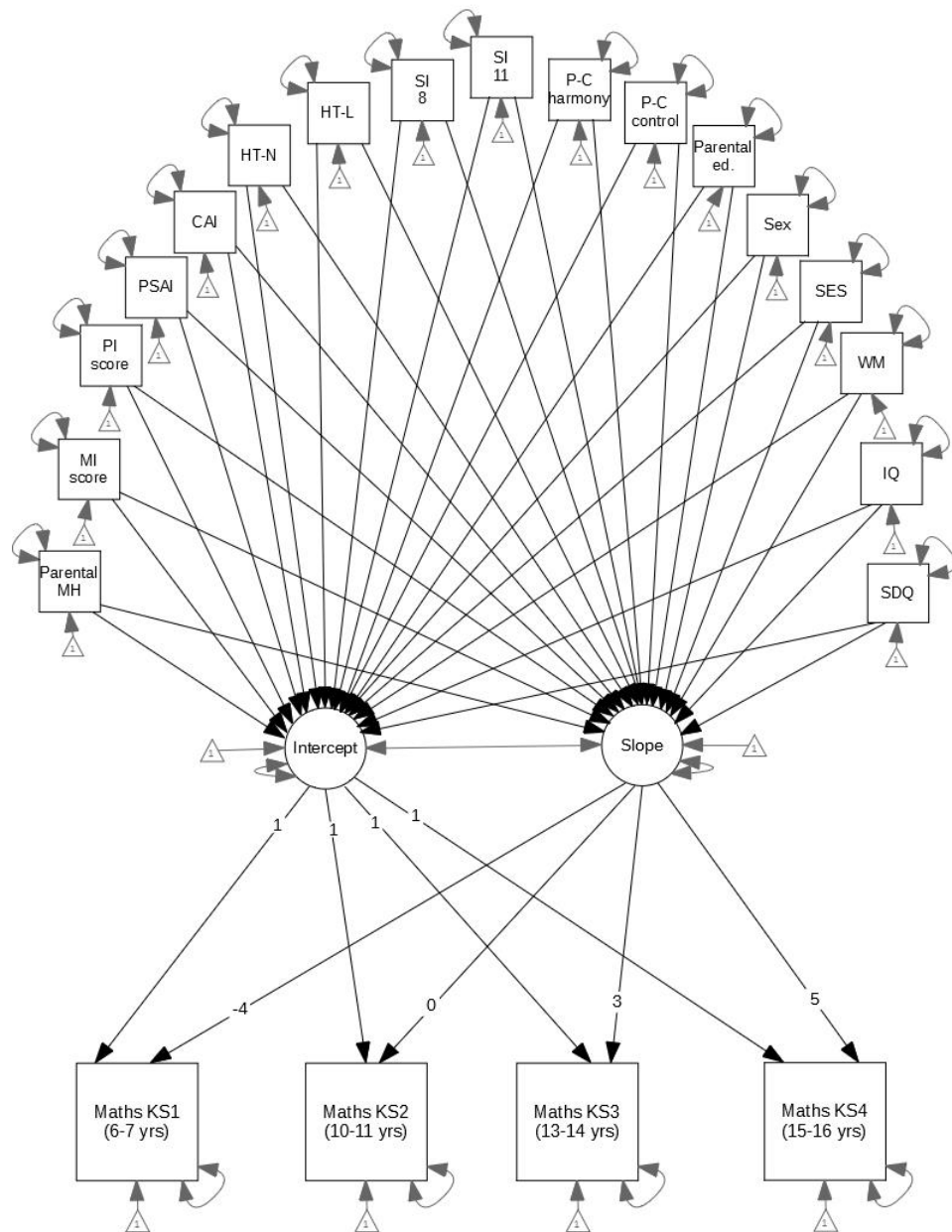


Figure 3. Latent growth model for maths attainment trajectories pre-transition to secondary

education. The intercept represents maths attainment at age 11, and the slope represents maths attainment from age 7 to 16. Paths between predictor variables are implied but not illustrated.

KS = key stage, MH = mental health, MI = mother's interaction score, PI = partner's interaction score, PSAI = gendered play (3.5 years), CAI = gendered play (8 years), HT-N = home-teaching (numeracy), HT-L = home-teaching (literacy), SI = school involvement, PC = parent-child, ed. = education, WM = working memory, SDQ = internalising symptoms.

Scores for SES, IQ, working memory and gendered play (CAI & PSAI) were centred so that the effects would be expressed at average levels of these predictors as opposed to them being zero. A previous study (Evans et al., 2020) found working memory and internalising symptoms predicted maths attainment in this sample, so these were included as predictors to adjust for their effects. All predictor variables were entered into the model simultaneously.

Results

Descriptive statistics and model fit

Descriptive statistics for the model predictors and outcomes are presented in Table 4. Table 5 shows a matrix of the correlation coefficients for the numeric predictors and outcome variables. The latent growth model provided satisfactory fit indices, CFI = 0.939, TLI = 0.881, RMSEA = 0.092 [90% CI = 0.089, 0.095], SRMR = 0.043.

Table 4.

Summary statistics for the key study measures.

| Measure | <i>n</i> | Min | Max | <i>Mdn</i> | <i>M</i> | 95% CI | <i>s</i> | % MD |
|-------------------|----------|-------|--------|------------|----------|------------------|----------|------|
| SDQ | 5664 | 0.00 | 17.00 | 2.00 | 2.39 | [2.32, 2.46] | 6.52 | 24% |
| IQ | 5651 | 49.00 | 151.00 | 106.00 | 106.44 | [106.04, 106.85] | 240.39 | 24% |
| WM | 5336 | 0.00 | 42.00 | 19.00 | 19.19 | [18.99, 19.40] | 58.03 | 29% |
| SES | 6165 | 23.72 | 95.70 | 58.40 | 59.17 | [58.88, 59.46] | 136.64 | 17% |
| Parental MH | 6917 | -1.52 | 4.64 | -0.24 | -0.04 | [-0.06, -0.02] | 0.84 | 7% |
| Interaction (M) | 6358 | 9.81 | 31.56 | 23.56 | 23.36 | [23.28, 23.44] | 10.59 | 15% |
| Interaction (P) | 5995 | 0.38 | 31.00 | 17.56 | 17.27 | [17.16, 17.38] | 19.37 | 20% |
| CAI | 5460 | 3.45 | 81.35 | 50.95 | 49.43 | [49.02, 49.85] | 244.29 | 27% |
| PSAI | 7050 | 4.25 | 95.55 | 49.35 | 49.16 | [48.80, 49.52] | 240.48 | 6% |
| Home teaching (L) | 7263 | 0.00 | 2.00 | 1.00 | 0.99 | [0.97, 1.00] | 0.54 | 3% |
| Home teaching (N) | 7263 | 0.00 | 2.00 | 1.00 | 1.33 | [1.31, 1.35] | 0.55 | 3% |
| SI (8) | 3429 | 0.00 | 4.00 | 1.00 | 1.85 | [1.82, 1.89] | 1.18 | 54% |
| SI (11) | 3943 | 0.00 | 4.00 | 1.00 | 1.75 | [1.72, 1.78] | 1.13 | 47% |
| Parent-child (H) | 5167 | 0.00 | 4.00 | 3.00 | 3.24 | [3.22, 3.26] | 0.64 | 31% |
| Parent-child (C) | 5176 | 0.00 | 4.00 | 2.00 | 1.95 | [1.92, 1.98] | 1.28 | 31% |
| KS1 Maths (7) | 5581 | 0.00 | 3.00 | 2.00 | 2.29 | [2.28, 2.31] | 0.29 | 25% |
| KS2 Maths (11) | 6110 | 1.00 | 6.00 | 4.00 | 4.33 | [4.32, 4.35] | 0.48 | 18% |
| KS3 Maths (14) | 5275 | 1.00 | 8.00 | 6.00 | 6.25 | [6.21, 6.28] | 1.37 | 29% |
| KS4 Maths (16) | 5708 | 2.00 | 10.00 | 7.00 | 7.37 | [7.33, 7.41] | 2.46 | 24% |

Note. Child's age in years are given in brackets for duplicate measures. SDQ = internalising symptoms, WM = working memory, MH = mental health (factor scores), interaction M and P = mother's home interaction and partner's home interaction, CAI = gendered play (8 years), PSAI = gendered play (3.5 years), home teaching N and L = numeracy and literacy, SI = school involvement, parent-child H and C = harmony and control, KS = key stage, MD = percentage of missing data per variable.

Table 5.

Correlation matrix for variables in the model predicting maths attainment.

| Variable | <i>M</i> | <i>SD</i> | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|-----------------------|----------|-----------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1. SDQ | 2.39 | 2.55 | | -0.09 | -0.06 | -0.05 | 0.22 | -0.06 | -0.09 | -0.07 | -0.06 | 0.00 | 0.00 | 0.01 | -0.04 | 0.00 | -0.02 | -0.10 | -0.15 | -0.13 | -0.11 |
| 2. IQ | 106.44 | 15.50 | 0.00 | | 0.35 | 0.28 | -0.02 | 0.00 | 0.06 | 0.07 | 0.02 | 0.09 | 0.07 | 0.15 | 0.14 | 0.08 | 0.06 | 0.47 | 0.57 | 0.65 | 0.59 |
| 3. WM | 19.19 | 7.62 | 0.00 | 0.00 | | 0.17 | 0.00 | -0.04 | 0.00 | 0.02 | 0.00 | 0.04 | 0.05 | 0.08 | 0.08 | 0.03 | 0.06 | 0.26 | 0.35 | 0.36 | 0.33 |
| 4. SES | 59.17 | 11.69 | 0.00 | 0.00 | 0.00 | | -0.02 | 0.01 | 0.10 | 0.04 | -0.01 | 0.02 | 0.02 | 0.14 | 0.16 | 0.03 | 0.01 | 0.19 | 0.24 | 0.29 | 0.32 |
| 5. Parental MH | -0.04 | 0.92 | 0.00 | 0.16 | 0.75 | 0.07 | | -0.06 | -0.10 | 0.00 | 0.00 | 0.01 | 0.01 | -0.05 | -0.08 | 0.00 | 0.01 | -0.04 | -0.04 | -0.05 | -0.06 |
| 6. Interaction (M) | 23.36 | 3.25 | 0.00 | 0.73 | 0.02 | 0.39 | 0.00 | | 0.34 | -0.04 | -0.02 | 0.22 | 0.22 | 0.08 | 0.06 | 0.02 | 0.02 | 0.00 | -0.01 | 0.00 | 0.01 |
| 7. Interaction (P) | 17.27 | 4.40 | 0.00 | 0.00 | 0.91 | 0.00 | 0.00 | 0.00 | | 0.01 | 0.05 | 0.15 | 0.15 | 0.05 | 0.10 | 0.04 | -0.01 | 0.05 | 0.05 | 0.08 | 0.08 |
| 8. CAI | 49.43 | 15.63 | 0.00 | 0.00 | 0.11 | 0.02 | 0.98 | 0.01 | 0.37 | | 0.60 | -0.04 | -0.03 | -0.01 | -0.05 | -0.02 | 0.08 | 0.06 | 0.09 | 0.08 | 0.02 |
| 9. PSAI | 49.16 | 15.51 | 0.00 | 0.12 | 0.99 | 0.46 | 0.76 | 0.13 | 0.00 | 0.00 | | -0.03 | -0.01 | -0.03 | -0.03 | -0.03 | 0.09 | 0.02 | 0.05 | 0.02 | -0.02 |
| 10. Home Teaching (L) | 0.99 | 0.74 | 0.92 | 0.00 | 0.00 | 0.17 | 0.25 | 0.00 | 0.00 | 0.00 | 0.02 | | 0.53 | 0.04 | 0.03 | 0.00 | 0.00 | 0.04 | 0.04 | 0.04 | 0.04 |
| 11. Home Teaching (N) | 1.33 | 0.74 | 0.80 | 0.00 | 0.00 | 0.25 | 0.44 | 0.00 | 0.00 | 0.05 | 0.43 | 0.00 | | 0.02 | 0.04 | 0.01 | -0.02 | 0.03 | 0.03 | 0.04 | 0.03 |
| 12. SI (age 8) | 1.85 | 1.09 | 0.74 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.01 | 0.52 | 0.05 | 0.01 | 0.40 | | 0.35 | 0.03 | -0.01 | 0.10 | 0.13 | 0.17 | 0.20 |
| 13. SI (age 11) | 1.75 | 1.07 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.06 | 0.05 | 0.03 | 0.00 | | 0.01 | 0.01 | 0.11 | 0.14 | 0.18 | 0.20 |
| 14. Parent-child (H) | 3.24 | 0.80 | 0.74 | 0.00 | 0.05 | 0.07 | 0.90 | 0.16 | 0.01 | 0.20 | 0.04 | 0.81 | 0.35 | 0.15 | 0.65 | | -0.07 | 0.09 | 0.06 | 0.12 | 0.11 |
| 15. Parent-child (C) | 1.95 | 1.13 | 0.31 | 0.00 | 0.00 | 0.46 | 0.35 | 0.09 | 0.48 | 0.00 | 0.00 | 0.97 | 0.15 | 0.60 | 0.68 | 0.00 | | 0.04 | 0.05 | 0.06 | 0.04 |
| 16. KS1 Maths | 2.29 | 0.54 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.71 | 0.00 | 0.00 | 0.24 | 0.01 | 0.06 | 0.00 | 0.00 | 0.00 | 0.03 | | 0.56 | 0.59 | 0.51 |
| 17. KS2 Maths | 4.33 | 0.70 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.58 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.77 | 0.68 |
| 18. KS3 Maths | 6.25 | 1.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.82 | 0.00 | 0.00 | 0.11 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.85 |
| 19. KS4 Maths | 7.37 | 1.57 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.70 | 0.00 | 0.12 | 0.21 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | |

Note. The upper triangle displays the correlation coefficients and the lower triangle displays the p values. SDQ = internalising symptoms, WM = working memory, MH = mental health, interaction M and P = mother's home interaction and partner's home interaction, CAI = gendered play (8 years), PSAI = gendered play (3.5 years), home teaching N and L = numeracy and literacy, SI = school involvement, parent-child H and C = harmony and control, KS = key stage.

Predictors of maths attainment at age 11 (intercept)

For maths attainment at age 11 (KS2), a score of 4 is the national average, though most children will achieve a score between 3 and 5, with very few students achieving lower than this, and only very few, exceptional students attaining a score of 6. The mean score for maths attainment at age 11 within this study was 4.3 ($SD = .7$), in line with national standards.

Table 6 shows the model parameters for predictors of the intercept of maths attainment (i.e. at age 11). The substantive predictors of this study were parental mental health, parent-child interactions (mother and partner), gendered play (PSAI and CAI), home-teaching (numeracy and literacy), parental education, parent-child relationships (harmony and control), and parental school involvement (age 8 and 11).

Of these variables, only parental education (O level, A level, and degree), gendered play (at age 3.5; PSAI), school involvement at age 11, and a harmonious parent-child relationship were significantly associated with maths attainment at age 11. For parental education, when compared to children with parents with a CSE qualification or lower, greater maths attainment was predicted by children having parents with an O level ($b = 0.142$), an A level ($b = 0.219$), and a degree ($b = 0.378$). There was no statistically significant difference in attainment for children whose parents had a vocational qualification compared to a CSE qualification ($p = .597$). School involvement at age 11 (but not age 8; $p = .153$), equated to a significant increase in maths attainment by 0.022 levels per extra activity participated in. A harmonious

parent-child relationship (but not child-control; $p = .209$), was associated with significantly higher maths attainment, with a 1-unit increase on the harmony scale equating to increases in maths by 0.038 levels.

Gendered play at age 3.5 was a significant predictor of maths attainment at age 11, where more masculine play and behaviours predicted decreased attainment. A 1-unit increase in PSAI score equated to decreased maths attainment by -0.002 levels. The remaining substantive predictors, namely parental mental health and aspects of the home environment (parent-child interactions, gendered play (age 8) and home-teaching), did not significantly predict maths attainment at age 11 (see table 6).

The contextual predictors included: sex, internalising symptoms, working memory, IQ, and SES. A higher IQ, greater working memory, higher SES, and male sex were all significant predictors of greater maths attainment at age 11. A 10-unit increase in IQ equated to a 0.20 increase in maths attainment. For working memory, 1 additional trial completed correctly equated to an increase of 0.013 levels in maths attainment. A 10-unit increase in SES equated to a 0.04 increase in maths attainment. Males maths attainment was 0.080 levels higher than females. Increased internalising symptoms significantly predicted decreased maths attainment; a 1-unit increase in SDQ score equated to a decrease in maths attainment by -0.017 levels at age 11.

Table 6.

Model parameters for predictors of the intercept of maths attainment (at age 11).

| Predictor | <i>b</i> | 95% CI | β | <i>p</i> |
|-------------------------------------|----------|------------------|---------|----------|
| Sex | 0.080 | [0.019, 0.142] | 0.055 | 0.011 |
| SDQ | -0.017 | [-0.024, -0.011] | -0.061 | 0.000 |
| IQ | 0.020 | [0.019, 0.022] | 0.433 | 0.000 |
| Working memory | 0.013 | [0.010, 0.015] | 0.133 | 0.000 |
| SES | 0.004 | [0.002, 0.006] | 0.066 | 0.000 |
| Edu: CSE vs. vocational | -0.024 | [-0.112, 0.064] | -0.007 | 0.597 |
| Edu: CSE vs. O Level | 0.142 | [0.078, 0.206] | 0.085 | 0.000 |
| Edu: CSE vs. A Level | 0.219 | [0.155, 0.283] | 0.143 | 0.000 |
| Edu: CSE vs. Degree | 0.378 | [0.304, 0.452] | 0.227 | 0.000 |
| Parental mental health | -0.019 | [-0.037, 0.000] | -0.023 | 0.053 |
| Mother's interaction score | -0.004 | [-0.009, 0.002] | -0.016 | 0.206 |
| Partner's interaction score | 0.003 | [-0.001, 0.007] | 0.016 | 0.204 |
| CAI score | 0.001 | [-0.000, 0.002] | 0.021 | 0.169 |
| PSAI score | -0.002 | [-0.004, -0.000] | -0.041 | 0.048 |
| Home teaching (literacy) | -0.001 | [-0.027, 0.026] | -0.001 | 0.960 |
| Home teaching (numeracy) | 0.003 | [-0.023, 0.030] | 0.003 | 0.811 |
| School involvement (age 8) | 0.012 | [-0.005, 0.029] | 0.018 | 0.153 |
| School involvement (age 11) | 0.022 | [0.005, 0.039] | 0.032 | 0.012 |
| Parent-child relationship (harmony) | 0.038 | [0.017, 0.059] | 0.042 | 0.000 |
| Parent-child relationship (control) | 0.010 | [-0.005, 0.024] | 0.015 | 0.209 |

Note. β is the standardized parameter estimate.

Predictors of the rate of change (maths attainment from age 7-16)

Table 7 shows the model parameters for predictors of the slope (i.e. the rate of change) of maths attainment from age 7 to 16. The group-level growth in maths attainment each year was 0.48, meaning that at average levels of the predictors, children progressed by close to half a national curriculum grade level each year, which is the expected progress in line with government recommendations.

Of the substantive variables specified above, parental education (O level, A level, and degree), school involvement (at age 11), parental mental health, gendered play (at age 3.5; PSAI), and a harmonious parent-child relationship were significantly associated with the rate of change in maths attainment over time.

For parental education, when compared to children with parents with a CSE qualification, increased growth in maths attainment was predicted by children to parents with an O level ($b = 0.021$), an A level ($b = 0.048$), and a degree ($b = 0.086$). There was no statistically significant difference in attainment growth for children whose parents had a vocational qualification compared to a CSE qualification ($p = .929$). School involvement at age 11 (but not age 8; $p = .108$), equated to a significant increase in maths attainment growth by 0.004 levels per year for each extra activity participated in. A harmonious parent-child relationship (but not child-control; $p = .281$), was associated with a significantly faster rate of change in maths attainment, with a 1-unit increase on the harmony scale equating to increases in maths by 0.006 levels per year. Gendered play at age 3.5 significantly predicted a slower rate of change in maths attainment, with a 10-unit increase in PSAI score equating to a decrease in maths attainment per year by

–0.004 levels. Parental mental health predicted a slower rate of change in maths attainment, with a 1-unit increase in symptoms equating to decreased maths attainment growth per year by -0.004 levels. Parent-child interactions, gendered play (at age 8; CAI) and home-teaching, did not significantly predict the rate of change in maths attainment (see table 7).

The significant contextual predictors of growth in maths attainment over time were sex (male), greater IQ, higher SES, greater working memory and fewer internalising symptoms. Being male equated to increased growth of 0.014 levels per year in maths. A 10-unit increase in IQ and SES increased the rate of change by 0.03 and 0.01 levels respectively. For each trial of the working memory task completed correctly, the rate of change in maths increased by 0.002. Greater internalising symptoms decreased the rate of change in maths per year by -0.002 for a 1-unit increase in SDQ score. However, these effects are extremely small within the context of a group-level rate of change of 0.48 levels in maths per year.

Table 7.

Model parameters for predictors of the slope of maths attainment.

| Predictor | <i>b</i> | 95% CI | β | <i>p</i> |
|-------------------------------------|----------|------------------|---------|----------|
| Sex | 0.014 | [0.002, 0.027] | 0.059 | 0.027 |
| SDQ | -0.002 | [-0.003, -0.001] | -0.044 | 0.003 |
| IQ | 0.003 | [0.002, 0.003] | 0.356 | 0.000 |
| Working memory | 0.002 | [0.001, 0.002] | 0.111 | 0.000 |
| SES | 0.001 | [0.000, 0.001] | 0.077 | 0.000 |
| Edu: CSE vs. vocational | -0.001 | [-0.018, 0.017] | -0.001 | 0.929 |
| Edu: CSE vs. O Level | 0.021 | [0.008, 0.033] | 0.076 | 0.001 |
| Edu: CSE vs. A Level | 0.048 | [0.035, 0.060] | 0.189 | 0.000 |
| Edu: CSE vs. Degree | 0.086 | [0.071, 0.101] | 0.314 | 0.000 |
| Parental mental health | -0.004 | [-0.008, -0.000] | -0.031 | 0.036 |
| Mother's interaction score | 0.000 | [-0.001, 0.001] | -0.003 | 0.826 |
| Partner's interaction score | 0.000 | [-0.001, 0.001] | 0.008 | 0.620 |
| CAI score | 0.000 | [-0.000, 0.000] | -0.009 | 0.653 |
| PSAI score | 0.000 | [-0.001, -0.000] | -0.051 | 0.045 |
| Home teaching (literacy) | -0.002 | [-0.007, 0.004] | -0.010 | 0.546 |
| Home teaching (numeracy) | 0.002 | [-0.004, 0.007] | 0.010 | 0.559 |
| School involvement (age 8) | 0.003 | [-0.001, 0.006] | 0.025 | 0.108 |
| School involvement (age 11) | 0.004 | [0.001, 0.008] | 0.037 | 0.017 |
| Parent-child relationship (harmony) | 0.006 | [0.001, 0.010] | 0.038 | 0.008 |
| Parent-child relationship (control) | 0.002 | [-0.001, 0.005] | 0.016 | 0.281 |

Note. β is the standardized parameter estimate.

Discussion

This study aimed to identify predictors of maths attainment trajectories across the transition from primary to secondary education, focusing on parental factors in childhood and adolescence. To recap, the study specifically investigated the following parental factors: mental health, home-teaching, parent-child interactions at home, parent-child relationships, school involvement, education qualifications, and child gendered play as substantive predictors of children's maths attainment trajectories.

Summary of results: parental predictors

Broadly, the results provided support for *some* of the parental factors as predictors of maths attainment at the transition (the intercept), and the growth over time (the slope). When looking at the intercept, the factors found to be significantly associated with higher maths attainment at age 11 were greater parental education, a harmonious parent-child relationship, greater school involvement at age 11, and 'feminine' gendered play at age 3.5 years. Whereas, when predicting the slope, significant effects were found for greater parental education (increased rate of change (ROC)), poor parental mental health (slower ROC), 'masculine' gendered play at 3.5 years (slower ROC), school involvement at age 11 (increased ROC), and a harmonious parent-child relationship (increased ROC).

For parental education, the gains in attainment increased as parents' education qualifications increased (i.e. having parents with a degree equated to the highest attainment). Although, there were no significant differences in maths attainment at age 11 and the rate of change over time between children to parents with a CSE (and below), and children to parents with vocational qualifications. Unsurprisingly, parental

education was found to be the strongest predictor of maths attainment at age 11, and of the rate in change over time, although, the effect sizes were slightly smaller in this study compared to previous analyses (Evans et al., 2020). One of the aims of this study was to help identify the underlying mechanisms in which greater parental education contributes to higher maths attainment, i.e. through increased participation in home-teaching, or in school activities for example. Given that aspects of parenting, the home-environment, and contextual factors like SES were adjusted for in the model, it seems there are unique ways that parental education contributes to maths attainment. One explanation could be genetic (Kovas et al., 2013; Shakeshaft et al., 2013). For example, parents that are more highly educated may pass on traits that are important for educational attainment (such as motivation and temperament, Eccles, 2005), and are also more likely to provide an environment that is intellectually stimulating (this is referred to as the passive gene-environment correlation/passive rGE; Plomin et al., 1977; Scarr & McCartney, 1983). Therefore, it could be that the differences between children of low- and highly-educated parents may be based upon genetic (or gene x environment) factors which were not captured in this analysis. Indeed, genetic components involved in maths attainment have been identified by previous research (e.g. Haworth et al., 2007; Kovas et al., 2007; Rimfeld, Kovas, Dale, & Plomin, 2015), however, this explanation is out of the scope of this analysis which focused on parenting factors that could be actively (*and arguably easily*) changed by parents. However, this finding does provide future suggestions for further research within this area.

Greater school involvement at age 11, but not age 8, predicted greater maths attainment at the time of the transition (i.e. age 11), with an additional activity on the scale (between 0-4), equating to an increase in maths attainment by 0.022 levels.

Moreover, greater school involvement at age 11 significantly predicted an increased rate of change in maths attainment over time, however, as with the intercept, involvement at age 8 did not significantly predict growth in attainment. This finding is broadly in line with existing research where small effect sizes have been reported ($r = .13$; Barger et al., 2019), suggesting that greater parental interest and involvement in school activities is important for maths grades to some extent. Although, the minimal effect of involvement at age 8 was unexpected. As discussed previously, parental support across the transition can buffer against the negative effects associated with the transition (Helsen et al., 2000; Newman et al., 2007; Rens et al., 2018), which could possibly explain why involvement at age 11 would be a stronger predictor than age 8 as it was measured just prior to the transition - meaning that those whose parents were more involved in school may have a more positive transition experience, thus reducing any negative effects on attainment.

A harmonious parent-child relationship at age 12 was associated with greater maths attainment at age 11 and an increased rate of change over time, whereas, child-control was not significantly associated with either. The finding that a harmonious parent-child relationship was linked to attainment was not surprising, however the effect size is somewhat smaller than in the existing literature ($\beta = 0.12 - 0.18$; Amato & Fowler, 2002). It was also expected that parent-child dyads where the child was more controlling (a proxy for autonomy) would be associated with greater attainment as it has been previously found that children with parents that provide greater autonomy support have more positive social, emotional, and academic outcomes (e.g. National Institute of Child Health and Human Development Early Child Care Research Network, 2008; Duineveld et al., 2017; Joussemet, Koestner, Lekes, & Landry, 2005; Ratelle, Larose,

Guay, & Senécal, 2005; Sher-Censor, Parke, & Coltrane, 2011). However, this idea was not supported by the findings of this study. It could be that ‘child-control’ was not a suitable proxy for child autonomy, or that neither parental control, nor child control is optimal for attainment, and that a more collaborative relationship is perhaps more beneficial for learning.

Gendered play at age 3.5 years, but not age 8, predicted the intercept and slope in maths attainment, with more ‘masculine’ play predicting lower maths attainment at age 11 and a slower rate of change over time. However, when placing these effects within the context of the scale of the PSAI (which ranges from 0-100), both effects are *extremely* small - a 10-unit increase in PSAI score would equate to a decrease of -0.02 in attainment at age 11, whereas, for the slope, even with a change of 100 units (i.e. the entire scale), the rate of change in maths attainment per year would be -0.04 . It is important to note that the average rate of change per year is half a national curriculum level (i.e. 0.48), which illustrates the extremely minimal effects of gendered play found here.

Parental mental health within the first few months following the child’s birth did not significantly predict maths attainment at age 11, but did marginally ($p = .05$) predict the slope in attainment in the expected direction where poorer mental health was linked to a slower rate of change. The effect of parental mental health on attainment was *extremely* small ($b = 0.019$) which was smaller than expected (Mensah & Kiernan, 2010). Previous research shows an increased risk of children not attaining a ‘pass’ grade in GCSE maths at age 16 whose mothers experience severe, persistent, or recurrent postnatal depression (Netsi et al., 2018 OR = 2.65; Pearson et al., 2016 $\beta = 1.52$). These

effects are much larger than what we found, however, in this study we focused on parental mental health combined as an indicator of the home environment rather than solely investigating maternal effects. This difference may explain the inconsistent findings as poor paternal mental health has not been found to predict maths attainment in previous studies (Pearson et al., 2016). Additionally, as this variable was measured in the first few months of life, it means that any changes over time (i.e. throughout childhood and adolescence), were not accounted for. Additional research would be beneficial in assessing any association between the trajectory of parental mental health and child maths attainment across the transition.

Home interaction scores (mother and partner), and home teaching (numeracy and literacy), did not significantly predict maths attainment at age 11, nor the slope over time which was unanticipated. Existing literature suggests that a greater participation in educational activities at home, and greater parent-child interaction is associated with higher maths (and general educational) attainment (Blevins-Knabe & Musun-Miller, 1996; Huntsinger et al., 2016; LeFevre et al., 2009; Manolitsis et al., 2013; Skwarchuk et al., 2014). Although, others have highlighted the inconsistencies within the literature (Bennett, 2017). The differences in findings of this study and the existing literature could be due to the measures used in this study. Home-teaching was measured through dichotomous measures of ‘yes’ and ‘no’ which were then combined, meaning that the score for each (numeracy and literacy), could only range from 0 (all ‘no’) to 2 (all ‘yes’). Moreover, parent-child home interactions were measured when the child was 3.5 years-old and 6.75 years-old and included various statements such as ‘mother plays with child with toys’ and ‘mother reads stories with child’. It could be that the questions asked were too general, and included basic activities that a large proportion of parents

would participate in with their child - meaning there would be little variation between participants, which is certainly true for the mother's interaction score. Whereas, the partner's interaction score had much more variance, though, this was still not a significant predictor. It could be that the timepoints used were at a time where children are still heavily reliant upon their parents for participation in daily activities (such as feeding and bathing), and it may be that a later age, where parental interaction is more varied between families, is potentially a more appropriate timepoint to focus on when looking at differences between children based upon parental interactions.

In summary, it seems that parental education, school involvement (at age 11), and a harmonious parent-child relationship are the most important parent-related factors found in this study that predict maths attainment trajectories in adolescence. These findings could be explained somewhat by the stage-environment fit theory proposed by Eccles and Colleagues (1989; 1993). The stage-environment fit theory describes that negative outcomes can occur when there is a mismatch between the developmental needs of an adolescent and the characteristics of their social environment. This means that adolescents whose social environments respond well to their changing needs are more likely to experience positive outcomes. It is possible that parents who are more involved in school are more aware of their child's changing needs across the transition to secondary education through greater interaction and discussion with their children (or their teachers), regarding school. Moreover, a positive (harmonious) parent-child relationship may mean that parents are perhaps more compassionate and accommodating when responding to their child's changing needs. It could be that when the changes in an adolescent's needs are appropriately met by their social environment,

the transition to secondary education is more successful, and as such, is associated with increased maths attainment.

Summary of results: contextual predictors

Sex, SES and IQ predicted maths attainment at the intercept (age 11), and the slope, with being male, having higher SES, and a higher IQ predictive of greater maths attainment and a quicker rate of change over time. As expected, internalising symptoms, and working memory predicted maths attainment trajectories, with a very small effect. These results are not discussed here in depth as they were included solely to adjust for them, see Evans et al. (2020) for further discussion of these findings.

It was expected based upon the wider literature and a previous study conducted by the authors on the same dataset (Evans et al., 2020), that IQ and socioeconomic status would predict maths attainment trajectories across the transition from primary to secondary education. Research investigating IQ and SES and attainment has found similar results (Bradley & Corwyn, 2002; Deary et al., 2007; Hadden et al., 2020), with this study adding further support to the existing literature.

In addition, it was expected that males would have greater maths attainment at age 11 (OECD, 2016a) which was supported by the findings of this study. However, the analysis also showed that that males had an increased rate of change over time, meaning that each year on average they made greater progress compared to their female peers, the effects were small, but this highlights the long-term negative effects associated with the gender gap in maths attainment.

Study limitations and future research directions

There are notable methodological issues that may affect the interpretation of these results. Firstly, the data were initially collected close to 30 years ago, meaning the findings could be less applicable now. This may be the case when investigating parental factors because the home environment has changed in the past 30 years with more mothers with young children in employment for example (Office for National Statistics, 2018). This possibility could mean that there are differences between maths attainment in this sample and children transitioning now given that parental presence at home is linked to a successful education transition (Waters et al., 2014).

Additionally, children's social environment has changed in a number of ways since the participants in this sample transitioned to secondary education between the years of 2001 and 2004. These changes include the increase in adolescents owning mobile phones and using social media apps and sites (Lenhart, Purcell, Smith, & Zickuhr, 2010; Ofcom, 2017), and increases in mental health issues (Pitchforth et al., 2019) meaning that the effects of the transition may be somewhat different for students now. For example, the social media sites Facebook and Twitter were launched in 2004 and 2006 respectively, meaning few children in this study would have had access to these sites before transitioning, and it is unlikely that a large percentage of them would have used them during secondary education. Other popular apps such as Instagram and Snapchat were launched in 2010 and 2011 which would have been after this sample had finished secondary education entirely. Whereas, adolescents transitioning now are already likely to use many of these sites/apps before transitioning (Children's Commissioner, 2018), or begin using them in early adolescence post-transition. A report

by the Children's Commissioner for England found that children using social media prior to secondary education focus on games and creative activities, whereas the focus post transition is on "likes" and "comments", affecting their emotional wellbeing (Children's Commissioner, 2018). Increased social media and phone use in adolescence has been linked to heightened depression and suicidal ideation in adolescents by other researchers also (Twenge, Joiner, Rogers, & Martin, 2018). These findings imply that a greater number of children transitioning now may encounter emotional difficulties around this period compared to children in this study, and given that emotional wellbeing predicts maths attainment trajectories (Evans et al., 2020), it is possible that transition experiences and attainment differs between these groups which affects the generalisability of the findings. Additional research utilising more recent data would help to further understand the impact of the transition in light of these changes in children's environments, and how they potentially alter the impact of the transition on psychological and academic outcomes.

There are many advantages of using a large birth cohort such as ALSPAC, for example the large sample size and breadth of topics assessed, however, there are also limitations including the high level of missing data, and the lack of depth for some of the measures. For example, in this study, numeracy home-teaching was measured using parents' self-report of whether they had taught their child numbers and shapes, this does not account for the wide range of other maths and numeracy teaching activities (such as cooking together, handling money in shops, and playing boardgames etc.) that help develop children's maths skills. Most of the measures also rely heavily on parents' abilities to identify their own behaviours and report them accurately and honestly. There are additional generalisability issues where children in ALSPAC achieve slightly higher

grades in national curriculum exams at age 16 and are more likely to be white with higher socioeconomic status compared to children not enrolled in the study (Boyd et al., 2013) suggesting that it would be beneficial to conduct additional research with a more diverse sample.

The findings show that other than parental education, two of the most important factors found by this study are a harmonious parent-child relationship, and parental school involvement at age 11. Although, a positive parent-child relationship relies on numerous factors, parental school involvement can be increased more easily, hopefully leading to gains in maths attainment. However, the present study only looked at four different kinds of involvement with school, whereas, there are many more ways parents can get involved with their child's education. For example, this study did not look at parent's help with homework, or their general interest in daily school life, which future research could focus on. Additional research investigating parental school involvement may help uncover which aspects are associated with the largest increases in maths, so that transition strategies could focus on improving these aspects.

Conclusion

The goal of the current study was to further understand which parental factors may influence maths attainment in adolescence. This study extends the existing literature by finding support for parental education qualifications, parental school involvement at age 11, and harmonious parent-child relationships as predictors of maths attainment. In addition, parental mental health in early childhood was not found to have a long-term impact and the findings show there is very little effect of gender-stereotyped play on maths attainment suggesting that sex differences in maths

attainment stem from other factors. General parent-child interactions and home-teaching were also not found to predict maths attainment suggesting that parents influence their child's maths attainment in other ways. However, due to some methodological limitations, additional research is still needed. Future exploration should aim to further uncover the relationship between parental education and children's maths attainment, with the goal to help close the associated gap in achievement between children to parents with higher qualifications and children to parents without educational qualifications. Failing to appropriately address these issues in early childhood further adds to the negative cycle of low maths attainment for parents and their children. Adults' low maths skills are associated with high unemployment rates and lower SES (NRDC, 2013; Parsons & Bynner, 1997; Ritchie & Bates, 2013), which as found in this study, is linked to their child's maths attainment also. Therefore, further work is needed to eradicate the 'maths crisis' in the UK, thus improving several long-term outcomes for individuals and wider society.

Chapter 5

Maths attitudes, school affect, and teacher characteristics as predictors of maths attainment trajectories in primary and secondary education

Chapter Prologue

As the final phase of the analyses using ALSPAC data, this chapter focuses on school and maths related factors and their associations with maths attainment trajectories. This study builds on the preceding chapters by investigating the school environment which is where children spend a considerable amount of their day outside the home environment and is where most of the changes associated with the transition occur. In this chapter, two models are used to assess the influence of affect towards school, teachers, and maths and teacher characteristics on maths attainment in primary education and secondary education separately. The aim of this chapter is to better understand school related predictors with the potential of informing school-based transition and maths strategies.

Abstract

Maths attainment is essential for a wide range of outcomes relating to further education, careers, health, and the wider economy. Research suggests a significant proportion of adults and adolescents are underachieving in maths within the UK, making this a key area for research. This study investigates the role of children's perceptions of the school climate (children's affect towards school and student-teacher relationships), their attitudes towards maths, and teacher characteristics as predictors of maths attainment trajectories, taking the transition from primary to secondary education into consideration. Two growth models were fit utilising secondary data analysis of the Avon Longitudinal Study of Parents and Children (ALSPAC). The first model, which looked at predictors of maths attainment in primary education, found significant associations only between positive maths attitudes and increased maths attainment. The second model, which looked at predictors of maths attainment in secondary education, found significant associations between increased maths attainment and positive maths attitudes, decreased school belonging, positive student-teacher relationships, and increased teacher fairness. The findings suggest that the secondary-education school environment is particularly important for maths attainment.

Introduction

Aspects of numerical and mathematical skills are used by adults every day. Whether this is as employees giving the correct change or when using spreadsheets, as consumers when calculating the savings associated with a 10% discount, when managing finances (i.e. understanding interest rates and borrowing funds), or as parents when helping children with homework (National Numeracy, 2019). The consequences of poor numeracy and low maths attainment are far-reaching and long-lasting. Low maths attainment limits educational and career opportunities, and is linked to a higher rate of unemployment and low socioeconomic status, as well as increased health issues, and a higher likelihood of homelessness and contact with the criminal justice system (Every Child a Chance Trust, 2009; Geary, 2011b; NRDC, 2013; Parsons & Bynner, 1997; Ritchie & Bates, 2013). Poor numeracy is reported to cost around 20.2 billion per year to the UK economy alone, not including the potential costs associated with the health sector and criminal justice system (Pro Bono Economics, 2014).

When quantifying the extent of poor mathematical abilities in the UK, it is reported that 49% of working-age adults have the equivalent maths skills of 6-year-old children, with only 22% having the skills of the ‘average’ 16-year-old (National Numeracy, 2018). However, these statistics are somewhat dated (using data from 2011), meaning that the true extent of the ‘maths crisis’ (Carey et al., 2019) currently is unknown. When comparing the data from 2011 to the first wave in 2003, the percentage of ‘numerate’ adults in the UK had decreased (National Numeracy, 2018), suggesting that it would not be entirely illogical to assume that the problem has continued to worsen from 2011 until now. The poor maths performance seen in adults in the UK is

likely due to deficits in childhood learning but could also be due to poor retention or a lack of practice of maths skills over time (see Geary, 2000). Investigating predictors of maths attainment in childhood provides several benefits in helping to overcome the ‘maths crisis’ present in the UK. By uncovering underlying factors that influence maths attainment, we can use this information to design evidence-based strategies, which will hopefully increase the effectiveness of interventions aiming to improve maths attainment and other positive outcomes associated with increased abilities.

Estimates of the heritability of maths suggest that attainment is moderately genetic - around two-thirds of the variance in attainment can be explained by genetic factors, with the remaining variance explained by aspects of the shared- and non-shared environment (Kovas et al., 2013), and their interaction with genetic factors. Outside of the home, a significant proportion of children’s time is spent in school. It is within this environment that children acquire new knowledge and skills and is also where significant social interactions with others take place. Unsurprisingly, existing research suggests the school environment is influential in the development of maths abilities and the performance of maths skills. However, the long-term effects are unknown. Therefore, the present study aims to investigate which school-related factors are longitudinally associated with maths attainment trajectories of school children in the UK, with a particular focus on the school climate, student-teacher relationships, and maths-related attitudes during the transitional period from primary to secondary education.

The transition from primary to secondary education

Early adolescence is a period of substantial change and development. One key event associated with considerable disruption during this time is the transition from primary to secondary education. In the UK, this transition occurs when children are 11 years old when they transfer from their 6th year of education in a primary school to their 7th year in a separate secondary school. The transition event itself is negatively associated with academic, social, and emotional wellbeing (Evans et al., 2018; Jindal-Snape, Hannah, Cantali, Barlow, & MacGillivray, 2020), with children experiencing increased feelings of anxiety, loneliness, and stress in during the transitional period (Benner & Graham, 2009; Chung et al., 1998; Coelho & Romão, 2016; Rice et al., 2011). Many changes occur within children's environments stemming from the transition, particularly relating to differences between primary and secondary education institutions. The differences present between these environments could plausibly influence relationships between maths attainment and the school climate, student-teacher relationships, and attitudes towards maths around the transition to secondary education, which will be discussed further in the following sections.

One clear environmental difference is that secondary schools are typically much larger than primary schools, with several primary education institutions 'feeding' into one secondary school. Children generally have several specialised subject teachers in secondary education compared to one individual teacher for all subjects for the entire school-year in primary education (though the presence of specialist maths teachers is becoming increasingly common in English primary schools, helped by government initiatives and training bursaries). Children report several concerns relating to this new

environment, such as becoming lost when navigating their new school buildings or being late for class (Akos & Galassi, 2004; Zeedyk et al., 2003). Prospective relationships in secondary education also cause some concern among children during the transition process, especially regarding bullying and making new student-teacher relationships (Zeedyk et al., 2003). The increased size of the physical and social environment, and the additional interactions between children and their unfamiliar teachers and peers likely affects children's perceptions of the school climate and student-teacher relationships, and how these factors are associated with attainment.

This transitional period in adolescence is particularly interesting when investigating maths attainment trajectories because of the impact of the education transition and the differences found in maths outcomes between primary and secondary education students. For example, students in secondary education report less involvement in maths class, less positive attitudes towards maths, decreased maths enjoyment, decreased maths interest and increased maths anxiety compared to primary-education students (Barth et al., 2011; Deieso & Fraser, 2019). These 'attitudes' towards maths (i.e. interest, enjoyment, self-efficacy and anxiety) are linked to maths attainment (Abu-Hilal, 2000; Chaman, Beswick, & Callingham, 2014; Chen et al., 2018; Dowker, Bennett, & Smith, 2012; Dowker et al., 2016; Else-Quest, Mineo, & Higgins, 2013; Pitsia, Biggart, & Karakolidis, 2017), highlighting the importance of this period for intervention strategies aiming to improve maths attainment. Further research also demonstrates poor maths performance across the transition where declines in achievement and a lack of progress in maths has been found (Akos et al., 2015; Alspaugh, 1998; Serbin et al., 2013), which has been linked to increased maths anxiety at age 18 (Field et al., 2019).

The changes found in attitudes towards maths (i.e. declining efficacy and interest) across the primary-secondary education transition appear to be related to aspects of the school environment, such as post-transition teacher effectiveness (Barth et al., 2011). Midgley et al. (1989b) found that maths attitudes (i.e. value, usefulness and importance) significantly declined for students moving from teachers they perceived to be highly supportive pre-transition to teachers they perceived to be less supportive post-transition, which was particularly marked for low-achieving students. These findings together suggest that the wider school environment is especially important for maths-related outcomes across the transition to secondary education, and that the differing characteristics of primary and secondary education environments should be investigated further when assessing maths attainment in adolescence.

School-related predictors of maths

The school climate and children's affect towards school.

The 'school climate' has been defined as the 'norms, goals, values, interpersonal relationships, teaching and learning practices, and organizational structures' of a school, and relatedly, children's affect towards school encompassing their feelings of social, emotional and physical safety (Cohen, McCabe, Michelli, & Pickeral, 2009, p. 182). A positive school/classroom climate, favourable affect towards school, and an academically-focused environment is positively associated with children's general academic and maths attainment (Collins & Parson, 2010; Goddard, Sweetland, & Hoy, 2000; Heck, 2000; Jia et al., 2009; Maxwell, Reynolds, Lee, Subasic, & Bromhead, 2017; Thapa, Cohen, Guffey, & Higgins-D'Alessandro, 2013). Students perceiving their classroom to be highly emotionally supportive are more likely to seek help from their teachers and

peers, which consequently is related to increased maths attainment (Schenke, Lam, Conley, & Karabenick, 2015). The school climate is also associated with adolescents' wellbeing (Jia et al., 2009; Lester & Cross, 2015), with increased feelings of 'school connectedness' associated with decreased emotional distress, suicidal involvement, violence, and substance use in US adolescents (Resnick et al., 1997).

There are several changes within the school environment that occur with the transition to secondary education which makes this transitional period particularly interesting in terms of the school climate. Children transition from being the oldest in the school to the youngest in a larger, very unfamiliar environment, likely affecting their sense of security. The total number of students also increases significantly from primary to secondary education, with teachers typically interacting with multiple classes of children in different years throughout the school day, meaning that children have a decreased capacity to develop close relationships and attachments like they had with their teachers in primary education (Eccles et al., 1993). These differences in the primary and secondary school environment, and those highlighted previously, could affect adolescents' perceptions of the school climate and their feelings towards school. It is likely that the change from a small classroom where children hold close relationships with their teachers, to a larger departmentalised school with an increased focus on discipline, affects their feelings of social, emotional, and physical safety. Findings reported by Coelho, Romão, Brás, Bear, and Prioste (2020) support this idea, highlighting the negative impact of the primary-secondary education transition on school climate, with declines in ratings of student-student relationships, fairness of rules, school safety, school liking and student-teacher relationships post-transition. However, the transition for Portuguese students in the study conducted by Coelho and

colleagues is one of the earliest primary-secondary education transitions to occur at age 9 compared to age 11 in the UK, meaning the effects could potentially be different for older students. Although, in a study of US schools, Kim, Schwartz, Cappella, and Seidman (2014) reports that ‘K-8’ schools (i.e. schools that do not transition in grade 6 or 7), had a more positive social context (defined as school chaos, student conduct problems, staff professional climate, teacher agency, and teaching burden) compared to middle- and junior high schools that do transition (usually into grade 6 or 7), suggesting that the negative impacts associated with the transition to secondary education reported by Coelho et al. are also evident in older adolescents. Positive school affect also appears to have a protective role; Vaz, Falkmer, et al. (2014) report an increased sense of ‘school-belonging’ (an aspect of school climate) in primary school is associated with decreased emotional symptoms concurrently, and in the first year of secondary education.

Student-teacher relationships. Overall, the existing literature suggests that a positive school climate is important for children’s academic attainment and their socio-emotional functioning. The aforementioned studies have used a range of definitions for ‘school climate’, however, one aspect that is commonly investigated within the school-climate literature is the relationship students have with their teachers. Various aspects of student-teacher relationships have been examined, though most studies focus on closeness, warmth, trust, and fairness perceived by students. Previous research has found that positive and warm student-teacher relationships buffer the effects of childhood adversity on aspects of cognitive abilities (Suntheimer & Wolf, 2020), and protects against depressive symptoms and misconduct in adolescents (Wang, Brinkworth, & Eccles, 2013). Positive student-teacher relationships are associated with

lower dropout rates for US high-school students (Barile et al., 2012) and influences student wellbeing (Van Petegem, Aelterman, Van Keer, & Rosseel, 2008). Others report associations between teacher mental health problems and students' mental wellbeing (Wang, Hu, & Wang, 2018).

As well as being important for general student-wellbeing, positive student-teacher relationships also play a pivotal role within maths attainment (Smedsrud et al., 2019). Increased student-teacher 'connectedness' is associated with increased maths attainment in Canadian adolescents, and also has a buffering effect between bullying and maths attainment for boys (Konishi, Hymel, Zumbo, & Li, 2010). Positive student-teacher relationships have been found to mediate the effects of school-level poverty on maths achievement in Chinese students (Xuan et al., 2019). Teng (2019) supports this finding, highlighting the importance of student-teacher relationships for the maths attainment of Chinese adolescents, with a marked effect for low-performing schools and underachievers. Negative relationships also appear to have an effect on attainment. Bryce, Bradley, Abry, Swanson, and Thompson (2019) found student-teacher conflict negatively impacted academic achievement (maths and reading) through behavioural engagement in US school children.

In addition to the effects associated with a positive student-teacher relationship, teachers' own attitudes, self-efficacy beliefs, and abilities can influence the development of students' attitudes towards maths regarding gender stereotypes (Gunderson et al., 2012), and can affect students' attainment (Gunderson et al., 2012; Thomson, Walkowiak, Whitehead, & Huggins, 2020). Teachers' enjoyment of maths also affects the instructional time given to maths in that teachers who enjoy maths more

spend more time engaging in maths tasks (Russo et al., 2020). There is also some evidence to suggest teachers' general mental wellbeing is linked to students' maths abilities through the quality of the classroom learning environment (McLean & Connor, 2015), and in the feedback given to students (McLean & Connor, 2018), which is particularly marked for low-achieving students. Research in this area is sparse, but generally suggests that teachers' mental health and their attitudes towards maths are linked to students' maths outcomes.

Similarly to the school climate, changes in student-teacher relationships have been reported around the transition to secondary education. In primary education, children are traditionally taught by a single teacher per year for all subjects (though primary schools are increasingly utilising specialist teachers in recent years) whereas, in secondary education, the majority of institutions are departmentalised in that adolescents will be taught different subjects by different specialist teachers. This difference between primary and secondary education is thought to alter the relationships students and teachers have (Coffey, 2013). For example, Hughes and Cao (2018) report a significant drop in teacher-rated 'warmth' around the transition to secondary education for US adolescents, with larger decreases in warmth predictive of lower maths attainment. Alternatively, Bru et al. (2010) report no abrupt change in student-perceived teacher support around the transition. These differences in findings could potentially lie within the respondent (student or teacher), the sample used (US versus Norway), or the specific aspects of the student-teacher relationship investigated, further highlighting the complexity of this association, and the need for further research in this area.

Stage-environment fit theory

One theoretical framework that may help to explain the negative effects and outcomes associated with the transition into secondary education is the stage-environment fit theory proposed by Eccles et al. (1993). This theory states that negative outcomes occur when there is a mismatch between adolescents' needs and the opportunities within their environments. Eccles and colleagues propose that there are developmentally inappropriate changes within the school and classroom environment following the transition to secondary education, which may result in a poor person-environment fit. The changes discussed by Eccles (1993) include a greater emphasis on teacher control and discipline, decreased opportunities for decision-making and responsibilities in class, fewer positive student-teacher relationships, whole-group task instruction (i.e. all students completing the same tasks in class and for homework assignments which increases social comparison, competitiveness, and evaluation concerns), public forms of evaluation and normative grading systems, and decreasing cognitive demands (i.e. through work involving copying from the board or textbooks). These changes are proposed to be damaging to motivational constructs post-transition and can therefore potentially affect attainment and socio-emotional adaptation to secondary education which could have long-lasting implications. Based on these changes, and the poor fit between adolescents' needs and those provided by the secondary education environment, it is plausible that the relationships between school-related predictors and maths attainment will differ between primary and secondary education.

The present study

To summarise, the transition to secondary education is regarded as a particularly stressful period for young adolescents. The transition coincides with biological, psychological, environmental, and social changes and is associated with negative outcomes, especially where adolescents fail to adapt to their new environment successfully. Various aspects of the school environment are associated with maths attainment, including the school climate, student-teacher relationships, and children's attitudes towards maths (often associated with teacher attitudes). These aspects are thought to differ substantially between primary and secondary education, often reported as a consequence of the transition event. However, there is an absence of research exploring the effects of the school climate (children's affect towards school and teacher characteristics), student-teacher relationships, and attitudes towards maths on maths attainment in primary and secondary education with little known of the potential long-term effects. Given the alarming state of the maths abilities of children and adults in the UK currently, identifying predictors of attainment early in development is important to allow for effective interventions. Therefore, the present study aims to explore the aforementioned factors as predictors of maths attainment trajectories in primary and secondary education.

This study presents two growth models examining variables in primary and secondary education. The models use secondary data from the Avon Longitudinal Study of Parents and Children (ALSPAC) to investigate predictors of the maths attainment trajectories (from age 7 to 16) of UK students. ALSPAC has been used in previous studies investigating school-related factors including risk factors for school exclusion

(Paget et al., 2018), the effects of peer victimisation (Wolke, Lereya, Fisher, Lewis, & Zammit, 2014), and examining school-related protective factors against negative outcomes for children experiencing maltreatment in early childhood (Khambati, Mahedy, Heron, & Emond, 2018). The current study is the final part of a three-phase study looking at predictors of maths attainment using the ALSPAC sample. The previous two phases (Evans & Field, 2020; Evans et al., 2020), which focused on the home environment, parental, cognitive, and emotional factors, showed that working memory, internalising symptoms, parent-child relationships, parental education and school involvement significantly predict maths attainment. The current final phase focuses on school-related predictors of maths attainment trajectories. The primary education model investigates the effects of children's affect towards school, relationships with teachers, attitudes towards maths, and primary-education teacher characteristics (affect towards teaching, mental wellbeing and self-esteem). The secondary education model investigates the effects of school belonging, negative emotion towards school, relationships with teachers, attitudes towards maths and children's feelings towards their secondary-education maths teacher. Primary education variables and secondary education variables are analysed separately as they are not comparable across the transition. It is hypothesised that greater positive affect towards the school environment, positive student-teacher relationships, and favourable attitudes towards maths and maths teachers will be associated with increased attainment in both primary and secondary education. It is predicted that teachers' self-rated characteristics (affect towards teaching, mental wellbeing and self-esteem) will predict maths attainment where increased self-esteem and fewer mental health symptoms will be associated with increased attainment.

Method

Sample

The Avon Longitudinal Study of Parents and Children (ALSPAC) recruited expectant mothers residing in the South West of England, due to give birth between the 1st of April 1991 and the 31st of December 1992 (Boyd et al., 2013; Fraser et al., 2013). The core ALSPAC sample consisted of 14,062 live births, of which 13,988 children were alive at 1 year. ALSPAC also recruited additional participants post-birth which resulted in a total sample size of 15,589 fetuses, of which 14,901 children were alive at 1 year. The sample is generally representative, however, there is a slight over-representation of white families with higher socioeconomic status (Boyd et al., 2013).

Data were collected from the child, the child's mother and her partner, and the child's school teachers, as well as education-linked data from the National Pupil Database (NPD). The majority of the data were collected through self-report postal questionnaires, with some of the data collected in 'Children in Focus' clinics, which a smaller sub-sample (10%) were invited to attend.

The study website contains details of all the data that is available through a fully searchable data dictionary and variable search tool (see <http://www.bristol.ac.uk/alspac/researchers/our-data/>). All participants provided written informed consent prior to the study. Ethical approval was obtained from the ALSPAC Ethics and Law Committee and the Local Research Ethics Committees. Informed consent for the use of data collected via questionnaires and clinics was obtained from participants following the recommendations of the ALSPAC Ethics and Law Committee at the time.

Sample exclusions. The sample exclusions here are the same as those in the first two phases of the project, presented in Evans et al. (2020) and Evans and Field (2020). Only data for singletons and the first-born twin were retained for analysis. Children identified as having special educational needs (SEN) at age 7 and/or age 11 were also excluded from analysis, as were children with English as an additional language (combined $n = 2,666$). Attrition was particularly high due to the longitudinal design, so participants lacking sufficient data (i.e. those with at least 50% missing data for the predictor variables) were excluded from analysis, leading to a final sample size of 6,490.

Outcome

Maths attainment. There are four key stages throughout children's compulsory education in England, with key stage 1 (age 5-7) and key stage 2 (age 7-11) in primary education, and key stage 3 (age 11-14) and key stage 4 (age 14-16) in secondary education. The maths attainment of primary- and secondary-education students is measured through examinations and assessments at the end of each key stage (i.e. at age 6-7, 10-11, 13-14, and 15-16).

In key stages 1-3, children's progress is evaluated using national curriculum levels which are numerical grades ranging from 1-8, with a higher score indicative of greater maths attainment. Governmental guidelines suggest that it is expected that children achieve a level 2 at key stage 1, a level 4 at key stage 2, and between levels 5-6 at key stage 3. At key stage 4, adolescents can achieve an alphabetical grade from the highest of 'A*', through 'A', 'B', 'C', 'D', 'E', 'F', 'G', and the lowest grade of a 'U'. To be comparable to maths attainment at the other key stages, these alphabetical grades

were coded into numerical grades with the highest being grade 10 (i.e. ‘A*’), down to the lowest grade of 2 (i.e. ‘U’). National curriculum levels for maths were obtained by ALSPAC from local education authorities for key stage 1 data, and the NPD for key stage 2-4 data (NPD variables: K2_LEVM, K3_LEVM, and KS4_APMAT), which consisted of a combination of teacher assessments and standardised tasks and tests. It is important to highlight that this scoring differs to the current grading system in England where key stage 3 tests are no longer administered, and where key stage 4 assessments are graded on a 1-9 scale.

In this study, the main outcomes were maths attainment in primary education just prior to the transition to secondary education (age 11; key stage 2), maths attainment post-transition to secondary education (age 14; key stage 3), and the growth in maths attainment over time.

Substantial predictors: primary education

Where measures were not pre-existing, validated questionnaires, measures were constructed from items in the ALSPAC dataset relating to common constructs. In these cases, a polychoric factor analysis and parallel analyses were used to determine items that could be combined. The *polychor* (Fox, 2019) and *nFactors* (Raiche & Magis, 2020) packages in R were used for these analyses and the *psych* (Revelle, 2019) package was used to determine internal consistency. Tables of all the individual items for each of the measures where composites were created is available in the Appendix.

Primary school affect. Children’s feelings towards primary school were assessed at age 11. Children were asked to report their feelings towards school and teachers by stating their agreement with 11 statements on a 4-point scale (*disagree*,

somewhat disagree, somewhat agree and agree; scored as 0-3). Example statements included: ‘my school is a place where my teacher listens to what I say’, ‘my school is a place where other pupils are very friendly’, and ‘my school is a place where I feel worried’.

A polychoric factor analysis revealed two factors determined by parallel analysis, relating to affect towards school, and relationships with teachers. Composites were created summing the scores for the items making up each factor, with possible scores for affect towards school ranging from 0-24 (8 items; such as ‘my school is a place where I get on well with the other pupils in my class’), and possible scores for relationships with teachers ranging from 0-9 (3 items; such as ‘my school is a place where my teacher treats me fairly in class’). A higher score indicates more positive affect towards school and teachers for both measures. Reliability was moderately high; Cronbach’s α was .80 and .75 for affect towards school and relationships with teachers respectively.

Attitudes to maths (age 10). Children’s attitudes towards maths in primary education were measured at age 10. Children were asked to rate their enjoyment, interest and abilities in maths by responding to 10 items on a 5-point scale (*not true, somewhat untrue, partly true, somewhat true and true*; scored as 0-4). Example items include: ‘I get good marks in maths’, ‘I enjoy doing work in maths’, and ‘I am bad at maths’. The responses were coded in a way that a higher score indicated more positive attitudes towards maths. Polychoric factor analysis and parallel analysis revealed a single factor, therefore, a composite was created summing the responses to all 10 items with possible scores ranging from 0-40. Cronbach’s α was high at .95.

Primary education teacher characteristics.

Measures related to teacher

characteristics were assessed in the final year of primary education (in year 6; when children are age 10-11). Three variables were included, consisting of the teacher's feelings towards teaching (teacher affect), their mental health, and their self-esteem. The teacher's affect towards teaching was measured by asking teachers to state their agreement (on a 5-point scale from *strongly disagree* to *strongly agree*; scored as 0-4) with 6 statements broadly covering their enjoyment of teaching, their confidence in and enjoyment of teaching numeracy, and how much they find teaching worthwhile. Polychoric factor analysis and parallel analysis revealed one factor for teacher affect, meaning a composite could be made. The score for teacher's affect was made from summing the scores for the 6 items, with a higher score referring to more positive affect towards teaching (ranging from 0-24). Cronbach's α was adequate at .71.

Teacher mental health and self-esteem were measured using the Crown-Crisp Experiential Index and the Bachman Self Esteem score. The Crown-Crisp Experiential Index (CCEI; Crown & Crisp, 1979) used by ALSPAC contains 23 items relating to somatic, depressive, and anxious symptoms. Possible scores range between 0 and 46, with a higher score corresponding to more symptoms. The Bachman Self Esteem score (Bachman & O'Malley, 1977) consists of 10 questions with a possible score between 0 and 40. A higher score relates to higher self-esteem. Cronbach's α for the aforementioned CCEI subscales ranges from .66 to .79 (Birtchnell, Evans, & Kennard, 1988), and α for the Bachman Self Esteem score is .75 (Bachman & O'Malley, 1977).

Substantial predictors: secondary education

Secondary school affect.

Feelings towards secondary school was measured at age 14. Adolescents were given the same 11 statements as the primary school affect measure above and were asked to rate their agreement with the statements on a 4-point scale (*strongly disagree*, *disagree*, *agree* and *strongly agree*; scored as 0-3). Example statements included: ‘my school is a place where I get on well with other pupils in my classes’, ‘my school is a place where I feel proud to be a pupil’, and ‘my school is a place where I feel lonely’. A polychoric factor analysis was conducted on the 11 items and parallel analysis revealed three factors relating to school belonging, negative emotion towards school, and relationships with teachers. Composites were created summing the scores for the items making up each of the three factors. Possible scores for school belonging (6 items) ranged from 0 to 18, for negative emotion (3 items) scores ranged between 0 and 9, and for relationships with teachers (2 items) scores ranged from 0 to 6. A higher score indicates greater school belonging, less negative emotion towards school, and more positive relationships with teachers. School belonging had high reliability (Cronbach’s $\alpha = .83$), relationships with teachers had moderately high reliability (Cronbach’s $\alpha = .72$), and negative emotion towards school had adequate reliability (Cronbach’s $\alpha = .64$).

Attitudes to maths (age 14).

Maths attitudes in secondary education were assessed at age 14. Adolescents were asked to indicate how much they enjoyed doing maths, how much they find what they learn in maths useful, and the level of importance they place on being good at maths. Maths enjoyment and usefulness were measured on 5-point scales (i.e. *doesn’t like it at all* to *likes it very much* and *not very useful* to *very*

useful; scored as 0-4). The level of importance adolescents placed on being good at maths was measured on a 4-point scale from *not at all important* to *very important* (scored as 0-3), which was recoded to be on a 5-point scale without a neutral option. A polychoric factor analysis was conducted on the three items and revealed one factor (using parallel analysis), therefore, a composite was made. The scores for each of the items were summed together with possible scores ranging from 0 to 12, with a higher score indicating positive attitudes towards maths. Reliability was moderately high; Cronbach's $\alpha = .68$.

Feelings towards maths teacher. At age 14, adolescents were given 18 statements regarding their feelings and perceptions of their maths teacher and were asked to rate their feelings on a 5-point scale (from *strongly disagree* to *strongly agree*; scored as 0-4). Using polychoric factor analysis and parallel analysis, two factors were found from the 18 items relating to positive teaching (12 items), and teacher fairness towards pupils (5 items). The scores for the individual items were summed to create two factors, for positive teaching scores could range from 0 to 48, and for teacher fairness possible scores could range from 0 to 20. Positive teaching included statements of teacher competence and measures of positive teaching practices such as 'my maths teacher understands maths really well', 'everyone is encouraged to do their very best', and 'my maths teacher gives us time to really explore and understand new things'. For teacher fairness, example items included: 'my maths teacher only cares about the clever students', 'my maths teacher treats boys and girls differently', and 'my maths teacher treats some students better than other students'. A higher score on both measures indicates more positive teaching practices and greater perceived teacher fairness

towards pupils. High reliability was found for both measures, Cronbach's $\alpha = .90$ and $.85$ for positive teaching practices and teacher fairness respectively.

Contextual predictors

Biological sex.

Biological sex was recorded at birth and included as a predictor due to potential differences in maths attainment between males and females. Females accounted for 55.3% of the sample. In both models, females were used as the reference group.

Socioeconomic status.

During the mother's pregnancy (at 32 weeks gestation), socioeconomic status (SES) of both parents (where available) was assessed using the Cambridge Social Interaction and Stratification Scale (CAMSIS). The CAMSIS measures occupational structure based upon social interactions (Prandy & Lambert, 2003). Scores can range between 1 (least advantaged) and 99 (most advantaged) with a mean of 50 and a standard deviation of 15 in the population (Ralston et al., 2016). The highest score of either parent (where both were available) was used in analysis.

Parental education.

Parental education qualifications have been shown to predict maths attainment trajectories in previous studies (Evans & Field, 2020). The child's parents were asked about their highest educational qualifications during pregnancy (at 32 weeks gestation), which were coded into the following 5 categories: no qualifications/no higher than CSE or GCSE, vocational qualifications (i.e. teaching or nursing qualifications), O-level or equivalent, A-level or equivalent, and university degree. The highest qualification held by either parent (if both were available) was used in analysis. 7.3% had a CSE or below, 4.9% had a vocational qualification, 25.1% had

an O level, 35.1% had an A level, and 27.5% had a degree. Having a CSE or below was used as the reference group in both models.

Parent-child relationships. Parent-child relationships were included based on previous findings (Evans & Field, 2020) and were evaluated using the Assessment of Mother–Child-Interaction with the Etch-a-Sketch (AMCIES; Wolke et al., 1995; Schneider et al., 2009) task during the ‘clinic in focus’ sessions at age 12.5. The AMCIES involves observing parent and child dyads while they play with an Etch-a-Sketch toy. Specifically, the dyads were asked to draw a house using the Etch-a-Sketch, with either the parent or child responsible for drawing horizontal lines, and the other responsible for drawing vertical lines. To complete the task successfully, parents and their children are required to work very closely together and assist one another. Following the task, the dyads were rated by the ALSPAC team on their ‘harmony’, i.e. whether the relationship between them and the observed interactions were particularly negative or positive. The following 5-point scale was used to code the interactions: *many conflicts* (scored as 0), *some conflicts (generally negative with some conflict)*, *neutral (atmosphere is neither positive or negative)*, *quite agreeable (generally positive)*, and *very agreeable (very positive and harmonious)* (scored as 4). A higher score refers to greater harmony (and a more positive relationship) between the parent and child. The AMCIES has shown good reliability in other samples (Cronbach’s $\alpha = .76-.80$; Jaekel, Wolke, & Chernova, 2012).

Parental school involvement. Parental involvement in school activities was rated by the child’s teacher at age 11. The activities included: ‘helping in class’, ‘helping with out of class activities’, ‘attending parent-teacher sessions’, and ‘being

involved in another school activity'. The child's teacher was asked to indicate whether the child's parents had been involved in any of these four activities by responding with *yes* or *no* to each activity, which were coded as 1 and 0 respectively. The responses for the 4 items were summed to create a score between 0 and 4, with a higher score indicating more parental involvement in school activities. Parental involvement in school has been found to predict maths attainment trajectories previously (Evans & Field, 2020).

Working memory and IQ. Working memory (at age 10) and IQ (at age 8) were assessed during 'Clinic in Focus' sessions. Children's total IQ score was measured using the performance (short-form tests: picture completion, picture arrangement, block design and object assembly, full-form test: coding) and verbal (short-form tests: information, similarities, arithmetic, vocabulary and comprehension) subscales of the Wechsler Intelligence Scale for Children (WISC-III; Wechsler, 1991). The scores for each of the short-form tests were transformed to be on the same scale as though the entire test had been administered to reduce fatigue. The WISC-III holds good test-retest reliability (.80-.89; Strauss et al., 2006).

Children's working memory capacity was measured using the Counting Span Task (Case et al., 1982) administered on a computer. In this task, children are presented with screens of red and blue dots and are asked to count them out loud. After counting them correctly, children are asked to recall the number of red dots on the screens, in the same order they are presented. All screens are displayed, regardless of the child's performance. Children were shown two practice screens followed by three sets of two screens, three sets of three screens, three sets of four screens, and three sets of five

screens, totaling to 42 trials. The global score was used representing the number of trials children answered correctly (i.e. 0-42). Both working memory and IQ are known predictors of maths attainment (Evans et al., 2020).

Internalising symptoms. Children's internalising symptoms at age 11 were measured using the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997), and were included in this study based on previous findings (Evans et al., 2020). The SDQ contains 25 items assessing emotional symptoms, peer problems, conduct problems, prosocial behaviour and hyperactivity. Parents rated their child's behaviour on each of the 5 subscales, with possible responses of *not true*, *somewhat true* and *certainly true*, which were coded as 0, 1, and 2 respectively, meaning that scores could range between 0 and 10 for each subscale. An 'internalising symptoms' score was created by summing the child's scores for the emotional symptoms and peer problems subscales, with possible scores ranging from 0-20. A higher score is indicative of greater internalising symptoms and problems. Example items of the internalising symptoms scale include 'child often seems worried' and 'child is rather solitary', 'tends to play alone'. The SDQ overall has good concurrent and predictive validity (Goodman, 1997), and satisfactory internal consistency (Cronbach's α for emotional difficulties = .66, and for peer problems α = .53; Stone et al., 2010).

Data analysis

Exclusions and missing data. This study follows the same exclusion criteria as in Evans et al. (2020) and Evans and Field (2020). The initial cohort was formed of 13,988 children alive at 1 year. Additional recruitment resulted in 14,901 children alive at 1 year (including singletons and twins; triplets and quadruplets were

excluded due to rarity). Withdrawal from the study led to a sample size of 14,684. Data from singletons and the first-born twin were retained for analysis ($N = 14,498$). Fourteen children were excluded as their first, or second main language was not English ($N = 14,484$). 2,652 children reported to have special educational needs (identified by teachers at ages 7-8 and 10-11) were excluded ($N = 11,832$). Where 50% or more of the data for the predictor variables were missing, 5,342 participants were excluded, leaving a final sample size of 6,490 (none of which were complete cases).

To address the issue of high attrition rates and missing data in the ALSPAC dataset (for missing data per variable see Table 8), multiple imputation was performed in R (R Core Team, 2017) using the *semTools* (Jorgensen et al., 2018) and *Amelia* packages (Honaker et al., 2011). Eighty imputations were performed, and the results were pooled (White et al., 2011). The outcome variables (maths attainment KS1-KS4) were included in the imputation model but were not imputed. Instead, to address the missing outcome data, Full Information Maximum Likelihood (FIML) estimation was used (Enders & Bandalos, 2001).

Statistical analysis strategy. All analyses were conducted in R version 3.4.3 (R Core Team, 2017). Two latent growth models predicting maths attainment trajectories in primary and secondary education were fit using the *lavaan* package (Rosseel, 2012), which are described in more detail below.

Primary education model. The primary education model evaluates the possible effects of variables measured in primary education, and whether these predict maths attainment trajectories across the transition from primary to secondary education. The variables entered into the primary education model were as follows: school affect,

student-teacher relationships, maths attitudes (age 10), teacher affect, teacher CCEI, teacher self-esteem, parental school support, child's sex, internalising symptoms, IQ, working memory, SES, parental education and parent-child relationships. These predictors were included as exogenous observed variables that predict the intercept and slope of growth in maths attainment.

Maths attainment at 7, 11, 14, and 16 years were endogenous observed variables predicted from latent variables representing the intercept and slope for growth in maths attainment over time. The loadings for the paths from the slope latent variable to the four maths attainment outcomes were constrained to be -4 (maths at age 7), 0 (maths at age 11), 3 (maths at age 14) and 5 (maths at age 16) so that the intercept represented maths attainment just prior to the school transition at age 11 (see Figure 4).

Secondary education model. The secondary education model focuses on the variables measured in secondary education, and whether these predict maths attainment trajectories following the transition from primary to secondary education. The variables entered into the secondary education model were as follows: school belonging, student-teacher relationships, negative emotions towards school, maths attitudes (age 14), positive maths teaching practices, maths teacher fairness, child's sex, internalising symptoms, IQ, working memory, SES, parental education and parent-child relationships. As with the primary education model, these predictors were included as exogenous observed variables that predict the intercept and slope of growth in maths attainment.

The same measures of maths attainment at 7, 11, 14, and 16 years were used as endogenous observed variables predicted from latent variables representing the intercept

and slope for growth in maths attainment. The loadings for the paths from the slope latent variable to the four maths attainment outcomes were constrained to be -7 (maths at age 7), -3 (maths at age 11), 0 (maths at age 14) and 2 (maths at age 16) so that the intercept represented maths attainment following the transition to secondary education at age 14 (see Figure 5).

For both models, all predictors were entered simultaneously. Correlation coefficients for the variables are displayed in Table 9 (primary education variables) and Table 10 (secondary education variables). SES, IQ, and working memory were all centred prior to analysis as there was no meaningful zero in these measures. For the primary education model, scores for school affect, teacher affect, student-teacher relationships, and teacher self-esteem were centred. For the secondary education model, scores for school belonging, student-teacher relationships, negative emotions towards school, positive maths teaching practices, and maths teacher fairness were centred.

Two previous studies (Evans & Field, 2020; Evans et al., 2020) found working memory, internalising symptoms, parental school support, parental education and a positive parent-child relationship significantly predicted maths attainment trajectories in this sample. Due to these findings, these predictors were also included in the present analysis to adjust for their effects.

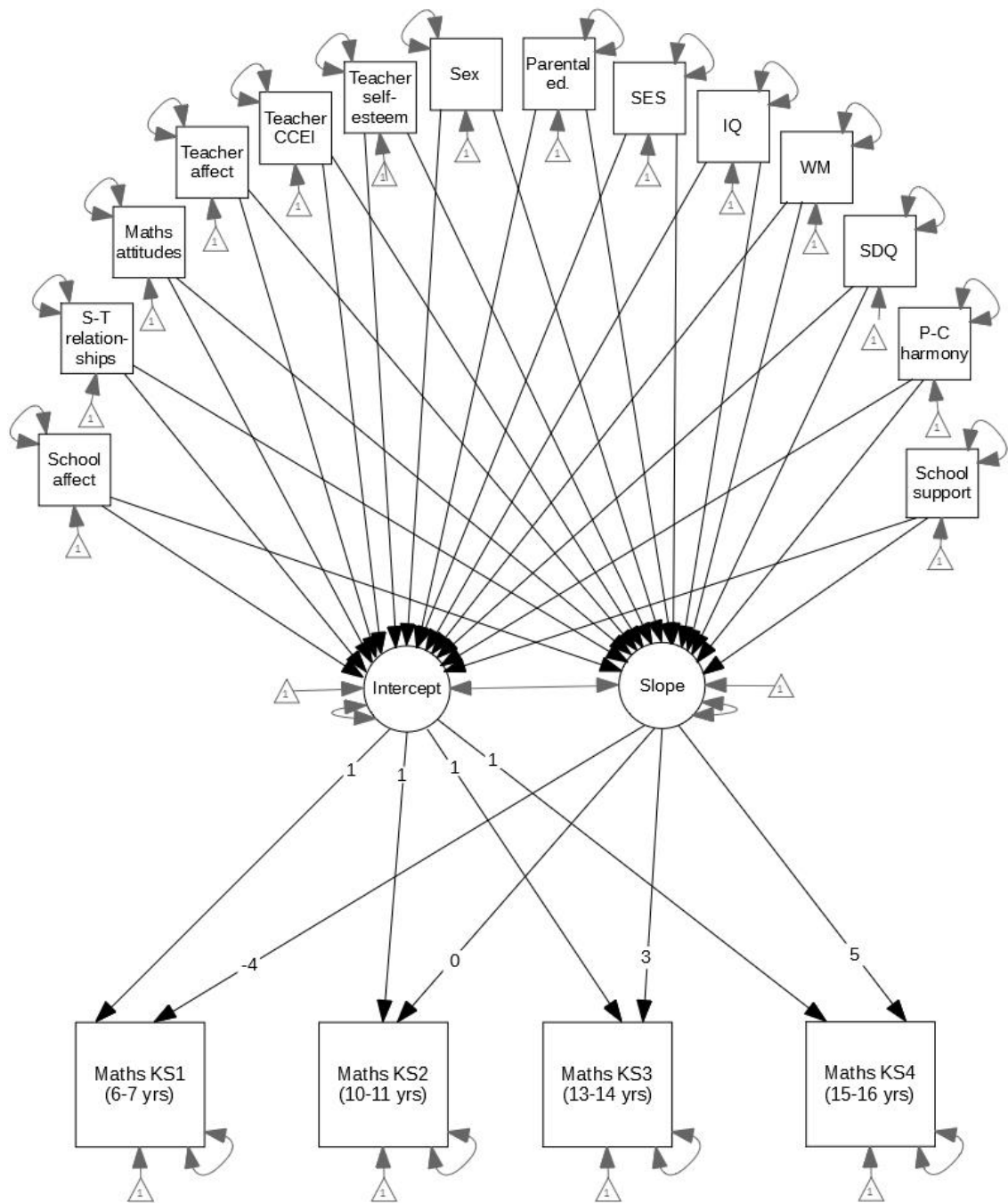


Figure 4. Latent growth model for maths attainment trajectories in primary education. The intercept represents maths attainment at age 11, and the slope represents maths attainment from age 7 to 16. Paths between predictor variables are implied but not illustrated. WM = working memory, SDQ = internalising symptoms, S-T = student-teacher, ed. = education, P-C = parent-child.

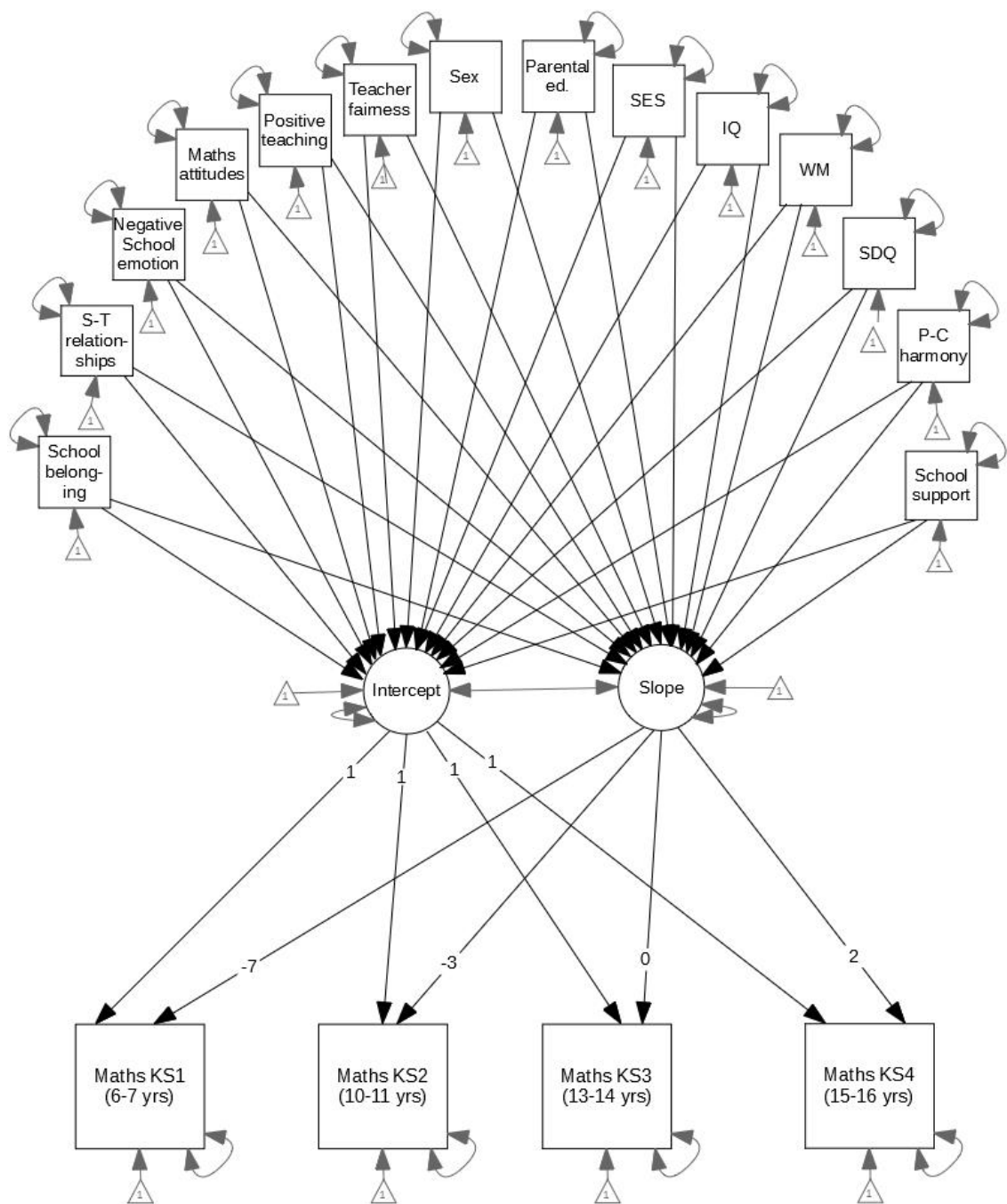


Figure 5. Latent growth model for maths attainment trajectories in secondary education. The intercept represents maths attainment at age 14, and the slope represents maths attainment from age 7 to 16. Paths between predictor variables are implied but not illustrated. WM = working memory, SDQ = internalising symptoms, S-T = student-teacher, ed. = education, P-C = parent-child.

Results

Descriptive statistics

Summary statistics for the variables in the primary and secondary education models are in Table 8. Maths grades were generally in line with national guidelines and expectations for all key stages. Children are expected to progress by half a grade each year in schools following the national curriculum in the UK. For both the primary education model (0.49 grades per year on average) and the secondary education model (0.46 grades per year on average), children's average growth in attainment per year was consistent with the wider population.

Both models provided satisfactory fit indices (primary education model: CFI = 0.936, TLI = 0.876, RMSEA = 0.104 [90% CI = 0.100, 0.107], SRMR = .05; secondary education model: CFI = 0.936, TLI = 0.876, RMSEA = 0.104 [90% CI = 0.101, 0.107], SRMR = .05).

Table 8.

Summary statistics for the key study measures.

| Measure | <i>n</i> | Min | Max | <i>Mdn</i> | <i>M</i> | 95% CI | <i>s</i> | % MD |
|-------------------------|----------|-------|--------|------------|----------|------------------|----------|------|
| School affect (P) | 5412 | 0.00 | 24.00 | 21.00 | 20.18 | [20.09, 20.27] | 11.38 | 17% |
| S-T relationships (P) | 5716 | 0.00 | 9.00 | 8.00 | 7.52 | [7.48, 7.56] | 2.82 | 12% |
| Maths attitudes (P) | 5390 | 0.00 | 40.00 | 32.00 | 29.35 | [29.08, 29.63] | 105.76 | 17% |
| Teacher affect (P) | 3631 | 5.00 | 24.00 | 20.00 | 19.43 | [19.32, 19.55] | 12.91 | 44% |
| Teacher CCEI (P) | 3698 | 0.00 | 38.00 | 11.00 | 12.97 | [12.72, 13.22] | 60.54 | 43% |
| Teacher self-esteem (P) | 3679 | 17.00 | 40.00 | 33.00 | 32.27 | [32.10, 32.45] | 28.82 | 43% |
| School belonging (S) | 3069 | 0.00 | 18.00 | 12.00 | 12.45 | [12.35, 12.55] | 7.90 | 53% |
| S-T relationships (S) | 4816 | 0.00 | 6.00 | 4.00 | 4.07 | [4.04, 4.10] | 1.29 | 26% |
| Negative emotion (S) | 3970 | 0.00 | 9.00 | 7.00 | 6.81 | [6.76, 6.86] | 2.36 | 39% |
| Maths attitudes (S) | 5404 | 0.00 | 12.00 | 8.00 | 8.25 | [8.19, 8.31] | 4.97 | 17% |
| Positive teaching (S) | 5317 | 0.00 | 48.00 | 34.00 | 32.76 | [32.55, 32.98] | 63.72 | 18% |
| Teacher fairness (S) | 5218 | 0.00 | 20.00 | 13.00 | 12.96 | [12.84, 13.08] | 19.52 | 20% |
| SES | 5135 | 26.31 | 95.70 | 58.40 | 59.65 | [59.33, 59.97] | 137.24 | 21% |
| IQ | 5185 | 49.00 | 151.00 | 107.00 | 107.19 | [106.77, 107.60] | 237.15 | 20% |
| WM | 5115 | 0.00 | 42.00 | 19.00 | 19.32 | [19.11, 19.53] | 57.39 | 21% |
| SDQ | 5489 | 0.00 | 20.00 | 2.00 | 2.37 | [2.30, 2.44] | 6.46 | 15% |
| Parent-child harmony | 5091 | 0.00 | 4.00 | 3.00 | 3.24 | [3.22, 3.26] | 0.63 | 22% |
| School support | 3770 | 0.00 | 4.00 | 1.00 | 1.78 | [1.74, 1.81] | 1.15 | 42% |
| KS1 Maths | 4961 | 0.00 | 3.00 | 2.00 | 2.32 | [2.31, 2.34] | 0.28 | 24% |
| KS2 Maths | 5476 | 1.00 | 6.00 | 4.00 | 4.37 | [4.35, 4.39] | 0.44 | 16% |
| KS3 Maths | 4713 | 1.00 | 8.00 | 6.00 | 6.35 | [6.31, 6.38] | 1.24 | 27% |
| KS4 Maths | 5137 | 2.00 | 10.00 | 8.00 | 7.50 | [7.45, 7.54] | 2.29 | 21% |

Note. P = measured in primary education, S = measured in secondary education, WM = working memory, SDQ = internalising symptoms, S-T = student-teacher, KS = key stage, MD = missing data.

Table 9.

Correlation matrix of the primary education measures and the contextual variables.

| Variable | M | SD | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|--------------------------|--------|-------|------|------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1. School affect | 20.18 | 3.37 | | 0.48 | 0.16 | 0.04 | 0.00 | 0.00 | 0.01 | 0.02 | 0.04 | -0.28 | 0.02 | 0.05 | 0.05 | 0.07 | 0.04 | 0.05 |
| 2. S-T relationships | 7.52 | 1.68 | 0.00 | | 0.11 | 0.02 | -0.01 | 0.02 | -0.01 | -0.02 | 0.02 | -0.12 | 0.03 | 0.06 | 0.00 | 0.01 | 0.01 | 0.02 |
| 3. Maths attitudes | 29.35 | 10.28 | 0.00 | 0.00 | | 0.03 | -0.03 | 0.02 | -0.01 | 0.14 | 0.15 | -0.10 | -0.01 | 0.05 | 0.22 | 0.29 | 0.27 | 0.22 |
| 4. Teacher affect | 19.43 | 3.59 | 0.05 | 0.39 | 0.14 | | -0.43 | 0.34 | 0.03 | 0.02 | 0.03 | 0.01 | -0.01 | 0.07 | 0.01 | 0.02 | -0.01 | 0.00 |
| 5. Teacher CCEI | 12.97 | 7.78 | 0.90 | 0.55 | 0.10 | 0.00 | | -0.49 | -0.06 | -0.03 | -0.04 | -0.01 | 0.01 | -0.02 | -0.03 | -0.05 | -0.02 | -0.02 |
| 6. Teacher self-esteem | 32.27 | 5.37 | 0.83 | 0.22 | 0.36 | 0.00 | 0.00 | | 0.04 | 0.00 | -0.02 | 0.00 | -0.01 | 0.04 | 0.01 | 0.01 | 0.00 | 0.00 |
| 7. SES | 59.65 | 11.72 | 0.37 | 0.36 | 0.37 | 0.12 | 0.00 | 0.04 | | 0.28 | 0.16 | -0.05 | 0.02 | 0.15 | 0.17 | 0.25 | 0.30 | 0.32 |
| 8. IQ | 107.19 | 15.40 | 0.19 | 0.32 | 0.00 | 0.39 | 0.10 | 0.95 | 0.00 | | 0.34 | -0.09 | 0.07 | 0.14 | 0.47 | 0.57 | 0.64 | 0.58 |
| 9. WM | 19.32 | 7.58 | 0.01 | 0.20 | 0.00 | 0.16 | 0.05 | 0.35 | 0.00 | 0.00 | | -0.06 | 0.02 | 0.08 | 0.26 | 0.34 | 0.36 | 0.32 |
| 10. SDQ | 2.37 | 2.54 | 0.00 | 0.00 | 0.00 | 0.45 | 0.46 | 0.83 | 0.00 | 0.00 | 0.00 | | -0.01 | -0.04 | -0.09 | -0.13 | -0.12 | -0.11 |
| 11. Parent-child harmony | 3.24 | 0.79 | 0.30 | 0.02 | 0.49 | 0.72 | 0.50 | 0.48 | 0.11 | 0.00 | 0.13 | 0.66 | | 0.01 | 0.09 | 0.05 | 0.11 | 0.09 |
| 12. School support | 1.78 | 1.07 | 0.00 | 0.00 | 0.01 | 0.00 | 0.29 | 0.02 | 0.00 | 0.00 | 0.00 | 0.01 | 0.58 | | 0.11 | 0.14 | 0.18 | 0.20 |
| 13. KS1 Maths | 2.32 | 0.53 | 0.00 | 0.78 | 0.00 | 0.59 | 0.06 | 0.76 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.54 | 0.56 | 0.50 |
| 14. KS2 Maths | 4.37 | 0.67 | 0.00 | 0.44 | 0.00 | 0.24 | 0.00 | 0.67 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.76 | 0.69 |
| 15. KS3 Maths | 6.35 | 1.11 | 0.01 | 0.68 | 0.00 | 0.76 | 0.31 | 0.79 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.85 |
| 16. KS4 Maths | 7.50 | 1.51 | 0.00 | 0.28 | 0.00 | 0.86 | 0.24 | 0.95 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |

Note. The upper triangle displays the correlation coefficients and the lower triangle displays the p values. S-T = student-teacher, SES = Socioeconomic status, WM = working memory, SDQ = internalising symptoms, KS = key stage.

Table 10.

Correlation matrix of the secondary education measures and the contextual variables.

| Variable | M | SD | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|----------------------------|--------|-------|------|------|------|------|------|------|-------|-------|------|-------|-------|-------|-------|-------|-------|-------|
| 1. School belonging | 12.45 | 2.81 | | 0.39 | 0.52 | 0.18 | 0.22 | 0.18 | 0.02 | -0.04 | 0.04 | -0.17 | 0.00 | 0.00 | 0.00 | 0.00 | -0.06 | -0.03 |
| 2. S-T relationships | 4.07 | 1.14 | 0.00 | | 0.34 | 0.19 | 0.26 | 0.31 | 0.07 | 0.10 | 0.07 | -0.06 | 0.04 | 0.08 | 0.09 | 0.11 | 0.17 | 0.21 |
| 3. Negative school emotion | 6.81 | 1.53 | 0.00 | 0.00 | | 0.10 | 0.13 | 0.16 | -0.07 | -0.10 | 0.00 | -0.21 | 0.00 | -0.01 | -0.01 | 0.00 | -0.01 | -0.01 |
| 4. Maths attitudes | 8.25 | 2.23 | 0.00 | 0.00 | 0.00 | | 0.45 | 0.30 | 0.00 | 0.06 | 0.06 | -0.04 | 0.02 | 0.02 | 0.11 | 0.15 | 0.21 | 0.20 |
| 5. Positive teaching | 32.76 | 7.98 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.62 | 0.00 | 0.04 | 0.01 | -0.04 | 0.02 | 0.00 | 0.06 | 0.07 | 0.12 | 0.11 |
| 6. Teacher fairness | 12.96 | 4.42 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.06 | 0.09 | 0.02 | -0.05 | 0.03 | 0.02 | 0.07 | 0.09 | 0.15 | 0.17 |
| 7. SES | 59.65 | 11.72 | 0.34 | 0.00 | 0.00 | 0.75 | 0.73 | 0.00 | | 0.28 | 0.16 | -0.05 | 0.02 | 0.15 | 0.17 | 0.25 | 0.30 | 0.32 |
| 8. IQ | 107.19 | 15.40 | 0.08 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | | 0.34 | -0.09 | 0.07 | 0.14 | 0.47 | 0.57 | 0.64 | 0.58 |
| 9. WM | 19.32 | 7.58 | 0.07 | 0.00 | 0.82 | 0.00 | 0.43 | 0.24 | 0.00 | 0.00 | | -0.06 | 0.02 | 0.08 | 0.26 | 0.34 | 0.36 | 0.32 |
| 10. SDQ | 2.37 | 2.54 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | | -0.01 | -0.04 | -0.09 | -0.13 | -0.12 | -0.11 |
| 11. Parent-child harmony | 3.24 | 0.79 | 1.00 | 0.01 | 0.77 | 0.32 | 0.30 | 0.05 | 0.11 | 0.00 | 0.13 | 0.66 | | 0.01 | 0.09 | 0.05 | 0.11 | 0.09 |
| 12. School support | 1.78 | 1.07 | 0.84 | 0.00 | 0.53 | 0.23 | 0.89 | 0.23 | 0.00 | 0.00 | 0.00 | 0.01 | 0.58 | | 0.11 | 0.14 | 0.18 | 0.20 |
| 13. KS1 Maths | 2.32 | 0.53 | 0.88 | 0.00 | 0.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.54 | 0.56 | 0.50 |
| 14. KS2 Maths | 4.37 | 0.67 | 0.88 | 0.00 | 0.84 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.76 | 0.69 |
| 15. KS3 Maths | 6.35 | 1.11 | 0.01 | 0.00 | 0.76 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.85 |
| 16. KS4 Maths | 7.50 | 1.51 | 0.16 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |

Note. The upper triangle displays the correlation coefficients and the lower triangle displays the p values. S-T = student-teacher, SES = Socioeconomic status, WM = working memory, SDQ = internalising symptoms, KS = key stage.

Primary education model

Predictors of maths attainment at age 11 (intercept).

Table 11 shows

the model parameters for the intercept of the primary education model. Of the substantive predictors, the only variable that significantly predicted maths attainment at the intercept was attitudes towards maths at age 10 ($p < .001$). School affect, student-teacher relationships, teacher-rated affect, teacher CCEI and teacher self-esteem did not significantly predict maths attainment (see Table 11). Of the contextual predictors, as expected, sex, parental education, SES, IQ, WM, internalising symptoms (SDQ), and parental school support all significantly predicted maths attainment at age 11.

Maths attitudes in primary education could range between 0 and 40 with a higher score indicating more positive attitudes towards maths. The effect size of maths attitudes on maths attainment in primary education was 0.012, meaning that an increase on the maths attitudes scale by 1 point equates to an increase in maths attainment at age 11 by 0.012 levels. When looking at this effect in context, this means that the difference between children with the most positive attitudes to maths (i.e. those scoring 40), compared to those with the lowest score (i.e. those scoring 0), the difference in attainment in primary education would be the equivalent to almost a year's progress in maths ($40 \times 0.012 = 0.48$).

When looking at the contextual predictors, the results generally replicated previous findings; males were found to have slightly higher maths attainment, children to parents with a degree or A level had higher maths attainment compared to children to parents with a CSE or below, parents to children with vocational qualifications had lower attainment. Increased internalising symptoms predicted lower attainment, and

higher SES, IQ, working memory, parental school involvement, and increased parent-child harmony all predicted higher maths attainment at age 11 (see Table 11). For a detailed discussion of these findings, see Evans et al. (2020) and Evans and Field (2020).

Primary education predictors of the rate of change. Table 12 shows the model parameters for the slope of the primary education model (i.e. the rate of change over time). Of the substantive predictors, school affect, student-teacher relationships, teacher-rated affect, teacher CCEI and teacher self-esteem did not significantly predict maths attainment growth. Maths attitudes significantly predicted the slope of maths attainment, with more positive attitudes linked to an increased rate of change over time ($b = 0.001, p < .001$). However, this effect is extremely small - when comparing children with the most positive attitudes to children with the most negative, the associated difference in attainment per year is around .04 for the maths-positive students.

Of the contextual predictors, the significant predictors of an increased slope for maths attainment were parental education (for those with a degree or A level), and higher SES, IQ, working memory, parental school involvement and increased parent-child harmony. Increased internalising symptoms were associated with a decreased rate of change (see Evans et al., 2020).

Overall, the results for the primary education model suggest that the most important substantive predictor of maths attainment at age 11, and of the rate of change over time is attitudes towards maths, with general school affect and teacher characteristics lacking a substantial effect on maths attainment in primary education.

Table 11.

Model parameters for predictors of the intercept of maths attainment in primary education (age 11).

| Predictor | <i>b</i> | 95% CI | β | <i>p</i> |
|-------------------------|----------|------------------|---------|----------|
| School affect | 0.001 | [−0.004, 0.007] | 0.007 | 0.643 |
| S-T relationships | -0.001 | [−0.012, 0.010] | -0.003 | 0.810 |
| Maths attitudes | 0.012 | [0.010, 0.013] | 0.173 | 0.000 |
| Teacher affect | -0.003 | [−0.008, 0.002] | -0.017 | 0.223 |
| Teacher CCEI | -0.002 | [−0.004, 0.001] | -0.018 | 0.230 |
| Teacher self-esteem | -0.001 | [−0.005, 0.002] | -0.009 | 0.535 |
| Sex | 0.049 | [0.015, 0.082] | 0.036 | 0.004 |
| Edu: CSE vs. vocational | -0.092 | [−0.174, −0.010] | -0.030 | 0.028 |
| Edu: CSE vs. O Level | 0.052 | [−0.006, 0.110] | 0.033 | 0.078 |
| Edu: CSE vs. A Level | 0.132 | [0.075, 0.189] | 0.092 | 0.000 |
| Edu: CSE vs. Degree | 0.271 | [0.206, 0.336] | 0.178 | 0.000 |
| SES | 0.004 | [0.003, 0.006] | 0.076 | 0.000 |
| IQ | 0.020 | [0.019, 0.021] | 0.450 | 0.000 |
| WM | 0.012 | [0.010, 0.014] | 0.133 | 0.000 |
| SDQ | -0.013 | [−0.020, −0.006] | -0.049 | 0.000 |
| Parent-child harmony | 0.038 | [0.017, 0.059] | 0.044 | 0.000 |
| School support | 0.025 | [0.009, 0.041] | 0.039 | 0.002 |

Note. β is the standardized parameter estimate.

Table 12.

Model parameters for predictors of the slope of maths attainment in primary education.

| Predictor | <i>b</i> | 95% CI | β | <i>p</i> |
|-------------------------|----------|------------------|---------|----------|
| School affect | 0.000 | [−0.001, 0.001] | −0.005 | 0.783 |
| S-T relationships | 0.001 | [−0.002, 0.003] | 0.012 | 0.509 |
| Maths attitudes | 0.001 | [0.001, 0.002] | 0.118 | 0.000 |
| Teacher affect | −0.001 | [−0.002, 0.000] | −0.025 | 0.151 |
| Teacher CCEI | 0.000 | [−0.001, 0.000] | −0.012 | 0.514 |
| Teacher self-esteem | 0.000 | [−0.001, 0.001] | −0.005 | 0.765 |
| Sex | 0.005 | [−0.002, 0.012] | 0.021 | 0.197 |
| Edu: CSE vs. vocational | −0.014 | [−0.032, 0.003] | −0.029 | 0.098 |
| Edu: CSE vs. O Level | 0.008 | [−0.005, 0.020] | 0.029 | 0.221 |
| Edu: CSE vs. A Level | 0.033 | [0.021, 0.045] | 0.140 | 0.000 |
| Edu: CSE vs. Degree | 0.069 | [0.055, 0.083] | 0.273 | 0.000 |
| SES | 0.001 | [0.001, 0.001] | 0.096 | 0.000 |
| IQ | 0.003 | [0.002, 0.003] | 0.364 | 0.000 |
| WM | 0.002 | [0.001, 0.002] | 0.109 | 0.000 |
| SDQ | −0.002 | [−0.003, −0.000] | −0.041 | 0.012 |
| Parent-child harmony | 0.006 | [0.001, 0.010] | 0.039 | 0.014 |
| School support | 0.005 | [0.002, 0.009] | 0.051 | 0.002 |

Note. β is the standardized parameter estimate.

Secondary education model

Predictors of maths attainment at age 14 (intercept).

The parameters

for the secondary education model are reported in Table 13. The statistically significant substantive predictors of maths attainment at age 14 were school belonging ($p = 0.001$), student-teacher relationships ($p < .001$), attitudes towards maths at age 14 ($p < .001$) and maths teacher fairness ($p = 0.002$). Negative emotion towards school, and positive teaching in maths did not significantly predict maths attainment in secondary education ($ps = 0.404$ and 0.118 respectively).

Unexpectedly, school belonging was negatively associated with attainment, meaning that students reporting greater school belonging in secondary education had lower maths attainment at age 14 ($b = -0.018$), however this effect was relatively small. Student-teacher relationships had a stronger effect on maths attainment ($b = 0.059$), whereby students rating their relationship with their teachers as more positive, had higher maths attainment. When comparing the lowest scores to the highest, this difference would equate to approximately one-third of a grade increase for the students rating their student-teacher relationships as highly as possible on the scale, which is generally a small effect.

Attitudes towards maths were associated with maths attainment in secondary education, where more positive attitudes equated to increased maths attainment. Maths attitudes could range from 0 to 12, meaning that a 1-unit increase for maths attitudes on this scale equated to an increase in attainment by 0.064 national curriculum levels. When comparing the lowest-rated maths attitudes (i.e. the most negative) to the highest-rated maths attitudes (i.e. the most positive), the difference in attainment would be

around 0.77 levels. Maths teacher fairness also significantly predicted maths attainment, with greater perceived fairness and equality equating to a 0.011 unit increase in attainment. However, this effect was extremely small.

When looking at the contextual predictors, all variables predicted maths attainment in regards to statistical significance (all $ps < .05$), with the only exception of parental education when looking at differences between children to parents with an O level compared to those with a CSE and below ($p = 0.101$). Being male, having higher SES, IQ and working memory were linked to higher attainment, greater internalising symptoms predicted decreased attainment, and both increased parent-child harmony, and parental school support equated to increased attainment (see Evans & Field, 2020 for further discussion).

Secondary education predictors of the rate of change. Table 14 shows the model parameters for the secondary education rate of change in maths attainment. Of the substantive predictors, school belonging, student-teacher relationships, maths attitudes and maths teacher fairness, all significantly predicted the slope of maths attainment (all $ps < .001$). Negative emotion towards school, and positive teaching in maths did not significantly predict growth in maths attainment (see Table 14).

Consistent with the intercept, greater school belonging predicted a slower rate of change in maths attainment, whereby a 1-unit increase in school belonging equated to a decrease in the rate of change by 0.003. However, this effect is extremely small, given that the average change in attainment was 0.46 grade levels per year. Similarly, the effects of student-teacher relationships and maths teacher fairness were also particularly small, with more positive student-teacher relationships and increased teacher fairness

associated with an increased rate of change by 0.009 and 0.002 respectively. More positive maths attitudes were linked to an increased rate of change ($b = 0.008$), suggesting that adolescents with a more positive attitude towards maths at age 14 progressed at a quicker rate, though ultimately, this is a small effect.

Of the contextual predictors, there were no significant differences in the rate of change between male and female students. Children to parents with a degree or A level had an increased rate of change. Higher SES, IQ, and working memory equated to an increased rate of change. Increased internalising symptoms equated to a slower rate of change and greater parent-child harmony and parental school involvement predicted a faster rate of change (see Evans & Field, 2020).

Generally, the results for the secondary education model suggest that there are aspects of the secondary school environment that are important for maths attainment trajectories within secondary education, and that there are also child-specific factors, specifically their attitudes towards maths, that have strong associations with maths attainment, however, broadly the effects on attainment were quite small.

Table 13.

Model parameters for predictors of the intercept of maths attainment in secondary education (age 14).

| Predictor | <i>b</i> | 95% CI | β | <i>p</i> |
|-------------------------|----------|------------------|---------|----------|
| School belonging | -0.018 | [-0.028, -0.007] | -0.047 | 0.001 |
| S-T relationships | 0.059 | [0.034, 0.084] | 0.066 | 0.000 |
| Negative school emotion | 0.008 | [-0.011, 0.027] | 0.012 | 0.404 |
| Maths attitudes | 0.064 | [0.052, 0.076] | 0.139 | 0.000 |
| Positive teaching | -0.003 | [-0.007, 0.001] | -0.026 | 0.118 |
| Teacher fairness | 0.011 | [0.004, 0.018] | 0.048 | 0.002 |
| Sex | 0.078 | [0.029, 0.128] | 0.038 | 0.002 |
| Edu: CSE vs. vocational | -0.122 | [-0.242, -0.002] | -0.027 | 0.047 |
| Edu: CSE vs. O Level | 0.071 | [-0.014, 0.156] | 0.030 | 0.101 |
| Edu: CSE vs. A Level | 0.224 | [0.140, 0.308] | 0.105 | 0.000 |
| Edu: CSE vs. Degree | 0.458 | [0.362, 0.554] | 0.201 | 0.000 |
| SES | 0.007 | [0.004, 0.009] | 0.076 | 0.000 |
| IQ | 0.028 | [0.026, 0.030] | 0.422 | 0.000 |
| WM | 0.019 | [0.015, 0.022] | 0.138 | 0.000 |
| SDQ | -0.022 | [-0.032, -0.012] | -0.055 | 0.000 |
| Parent-child harmony | 0.049 | [0.019, 0.080] | 0.038 | 0.002 |
| School support | 0.040 | [0.017, 0.063] | 0.042 | 0.001 |

Note. β is the standardized parameter estimate.

Table 14.

Model parameters for predictors of the slope of maths attainment in secondary education.

| Predictor | <i>b</i> | 95% CI | β | <i>p</i> |
|-------------------------|----------|------------------|---------|----------|
| School belonging | -0.003 | [-0.004, -0.001] | -0.061 | 0.001 |
| S-T relationships | 0.009 | [0.006, 0.013] | 0.093 | 0.000 |
| Negative school emotion | 0.001 | [-0.002, 0.003] | 0.010 | 0.600 |
| Maths attitudes | 0.008 | [0.006, 0.009] | 0.148 | 0.000 |
| Positive teaching | 0.000 | [-0.001, 0.000] | -0.030 | 0.150 |
| Teacher fairness | 0.002 | [0.001, 0.003] | 0.068 | 0.001 |
| Sex | 0.005 | [-0.002, 0.012] | 0.022 | 0.162 |
| Edu: CSE vs. vocational | -0.013 | [-0.030, 0.003] | -0.027 | 0.116 |
| Edu: CSE vs. O Level | 0.007 | [-0.004, 0.019] | 0.029 | 0.220 |
| Edu: CSE vs. A Level | 0.033 | [0.021, 0.044] | 0.138 | 0.000 |
| Edu: CSE vs. Degree | 0.067 | [0.053, 0.080] | 0.264 | 0.000 |
| SES | 0.001 | [0.001, 0.001] | 0.090 | 0.000 |
| IQ | 0.003 | [0.002, 0.003] | 0.357 | 0.000 |
| WM | 0.002 | [0.001, 0.002] | 0.118 | 0.000 |
| SDQ | -0.002 | [-0.003, -0.001] | -0.046 | 0.003 |
| Parent-child harmony | 0.005 | [0.001, 0.009] | 0.035 | 0.023 |
| School support | 0.005 | [0.002, 0.008] | 0.047 | 0.003 |

Note. β is the standardized parameter estimate.

Discussion

The aim of this study was to explore predictors of maths attainment trajectories in primary and secondary education by focusing specifically on the school climate and children's affect towards school, student-teacher relationships, teacher characteristics, attitudes towards maths and perceptions of the maths teacher.

Summary of main results

The primary education model investigated the associations between maths attainment trajectories of adolescents and their affect towards school, perceived student-teacher relationships, attitudes towards maths, and characteristics of their teacher (affect towards teaching, mental wellbeing and self-esteem) in primary education, while adjusting for known predictors and demographic variables. The only statistically significant predictor of maths attainment was children's attitudes towards maths, where more positive attitudes towards maths predicted increased attainment at age 11, and an increased rate of change (ROC) over time. The magnitude of the effect of maths attitudes for attainment at age 11 was moderate; a 10-unit increase on the maths attitudes scale equated to an increase in attainment by 0.12 national curriculum levels. When comparing children with the lowest score for maths attitudes (0), to the highest (40), this difference would be close to a year's worth of progress (i.e. almost half a grade level). The size of the effect on yearly progress was small; a 10-unit increase on the maths attitude scale equates to an increased ROC of .01 grade levels per year. Affect towards school, student-teacher relationships, and teacher characteristics were not found to significantly predict maths attainment at age 11, nor the ROC.

The secondary education model examined school belonging, negative emotion towards school, relationships with teachers, attitudes towards maths and perceptions of the maths teacher (positive teaching practices and fairness) in secondary education as predictors of maths attainment after adjusting for known predictors and demographic variables. School belonging, student-teacher relationships, maths attitudes, and maths-teacher fairness were significantly associated with maths attainment at age 14, and the ROC. Unsurprisingly, student-teacher relationships rated as more positive and greater maths-teacher fairness were associated with increased attainment trajectories, though the effects were relatively small. Maths attitudes were positively associated with maths attainment at age 14 and an increased ROC over time with a considerable effect size. School belonging was negatively associated with maths attainment, meaning that increased school belonging was linked to decreased maths attainment at age 14, and a slower ROC over time. Positive teaching practices in maths and negative emotion towards school were not significantly associated with maths attainment.

Based on the wider literature, it was expected that positive attitudes towards maths would be associated with increased attainment in both school environments, which was supported by the results with moderately large effect sizes present in both models. The findings suggest that children who enjoy maths and perceive it to be useful, interesting, and important, achieve higher grades than their peers who feel more negatively about maths. However, it is important to note that this result does not imply causality. It could be that enjoying maths increases grades through greater motivation, practice, and effort, but also, that feeling competent in maths and achieving good grades increases enjoyment. It is highly likely that there is a reciprocal relationship where attitudes affect achievement, and achievement affects attitudes, which has been found in

existing research (Pekrun, Lichtenfeld, Marsh, Murayama, & Goetz, 2017), however, this idea could not be examined in this study.

When looking at the findings for the secondary education model, it appears that school-related factors in secondary education have a greater effect on maths attainment trajectories, where more positive student-teacher relationships, greater perceived maths teacher fairness, and lower school-belonging were significantly associated with increased attainment. It was expected that positive student-teacher relationships and teacher fairness would be positively associated with attainment. However, it is somewhat surprising that student-reported school-belonging was negatively associated with attainment. It appears that the school-climate declines around the transition (Coelho et al., 2020), however, this still does not explain the negative association with maths as found here. One possible explanation is that the measure used for school belonging in this study contained items relating to the child's peer relationships, and as such, could reflect their perceived popularity. For example, items for the school belonging composite included 'my school is a place where I know people who think a lot of me', 'my school is a place where I get on well with other pupils in my classes', and 'my school is a place where other pupils are very friendly'. Therefore, it could be that adolescents who perceive their peers as more accepting and friendly, are those with a greater number of friendships and are considered 'popular', which has been associated with decreased attainment (Schwartz, Gorman, Nakamoto, & McKay, 2006). Another potential explanation could be that students who are especially 'gifted' in maths may not feel comfortable socially within their school or may not find it sufficiently challenging intellectually. Peer victimisation is high for gifted students (Peterson & Ray, 2006), and so it could be that high-achieving maths students do not view their

school as a place they get on well with other pupils. In addition, stronger mathematicians may feel less engaged by classwork they do not find particularly challenging, and so may not identify strongly with their school and their educational environment. However, additional research is needed to investigate these possibilities further.

The findings here support the idea that positive student-teacher relationships are an important part of the school climate associated with long-term positive outcomes. This measure generally focused on *all* teachers students interacted with. However, when focused on the adolescent's maths teacher specifically, this study found support for teacher fairness as a predictor of maths attainment trajectories, but not for positive teaching practices (relating to the perceived efficacy of the teacher, their encouragement, and their emphasis on the importance of effort). The significant finding of teacher fairness suggests that students who perceive their maths teacher as treating all students equally (regardless of gender or ability), had increased maths attainment trajectories. This is supported by existing research particularly on the damaging effects of gender-stereotypes in maths (e.g. Gunderson et al., 2012), and further demonstrates the importance of treating students equally, regardless of their characteristics and abilities.

Positive teaching practices (i.e. the teacher tries to make maths interesting, tells the class why maths is important, and understands maths really well) were not found to predict maths attainment significantly. This finding implies that the perceived competence of the maths teacher is not associated with students' maths attainment, and other teacher-related factors (such as teacher fairness) are more important in secondary

education. This finding is unexpected, however, one possible explanation for the absence of a significant finding could be that at average levels of teacher fairness (in the model this variable was centred), the instructional quality of teachers is less important. It could be that when students perceive themselves to be viewed equally, they are less likely to become disengaged with difficult work, regardless of their abilities and the competency of their teacher, provided that they are treated similarly to their peers. However, further analyses and research would be needed to explore this idea.

Negative emotion towards school, including feelings of loneliness, worry, and restlessness, was not found to significantly predict maths attainment. One possible explanation for the absence of a significant association could be that negative emotion towards school was measured at only one specific timepoint, meaning that any changes in affect towards school would not be accounted for. To illustrate, adolescents could be experiencing short-term but heightened stress and emotion towards school relating to exams or assessments, the breakdown of friendship groups, or issues with bullying and victimisation. Their feelings towards any school-related short-term stressors may have been reflected in their responses to the questionnaire but may not have been long-lasting enough to affect their overall attainment. However, this idea can only be speculated as multiple measures of emotion towards school over time were not available.

When looking at the results of the models together, there are several interesting findings. Firstly, the absence of a significant association between school- and teacher-related variables in primary education and maths attainment is surprising. Based on the existing literature, it was predicted that a positive school climate, a warm student-teacher relationship, and positive teacher characteristics (i.e. positive affect towards

teaching, high self-esteem, and fewer mental health symptoms) in primary education would be associated with increased maths attainment. These findings suggest that the effects associated with poor secondary education experiences could be more substantial than positive primary education experiences. It could be that the significant associations found in the secondary education model reflect the greater importance of the secondary education environment for attainment, or the lack of fit between adolescents' changing needs and their educational environment as proposed by the stage-environment fit theory (Eccles et al., 1993). Eccles et al. (1993) suggest that there are fewer opportunities for positive student-teacher relationships in secondary education, especially where children transition from having one teacher per year in primary education, to interacting with multiple teachers throughout the day in secondary education, which may help explain why student-teacher relationships were associated with maths attainment in secondary education but not in primary education. The school climate is also thought to differ substantially between primary and secondary education (such as a greater emphasis on discipline, social comparison, and public evaluation in secondary education) which could explain why children's affect towards school was associated with maths attainment in secondary education, but not in primary education. It appears that children experiencing maladaptive transitions to secondary education, where their needs are vastly different to their environment, are potentially the most at-risk of poor attainment, which is supported by previous research (Evans et al., 2018). Other possible explanations could be that the effects are due to the differences in measures used in both models, however, further analyses would be needed to assess this further.

Contextual predictors

These variables were included to adjust for known effects from previous studies. They are discussed in detail in Evans et al. (2020) and Evans and Field (2020), and so here we will briefly summarise the key points. The results suggest that males have significantly greater maths attainment at ages 11 and 14, but their rate of growth per year is not significantly different from females, implying that by early adolescence males have a slight grade-advantage. It is apparent that even when school-related factors and attitudes towards maths are adjusted for, there are still differences in maths attainment between adolescent males and females.

Unsurprisingly, greater IQ, SES, and working memory predicted greater attainment at age 11 and 14, and an increased rate of change over time in both models. Fewer internalising symptoms, greater parental school support and a more positive parent-child relationship were also associated with increased maths attainment trajectories in both models. Parental education qualifications were also found to significantly predict maths attainment trajectories. In both models, when compared to children of parents with a CSE qualification or below, having a vocational qualification was associated with decreased attainment (*NS* for the ROC), and having an A level or degree was associated with increased attainment. There were no significant differences between children to parents with an O level and a CSE or below for attainment at age 11 and 14 or the ROC. Overall, the findings indicate that higher levels of parental education qualifications are generally linked to increased maths attainment trajectories.

Implications, limitations, and future research directions

Together the findings suggest that the secondary education school environment and children's attitudes towards maths have important implications for children's maths attainment throughout school. Based on these findings, there are several recommendations for educational strategies to help improve maths attainment. We could not assess causal links in this study, but it appears that improving children's attitudes towards maths might help improve their attainment. This has been achieved by the Maths Counts programme (See, Morris, Gorard, & Siddiqui, 2019), however, it is likely that the associated increase in maths abilities prompted by this programme also increases children's attitudes towards maths.

Focusing predominantly on the secondary education environment could also be useful when targeting children's attainment. In this study, we found that student-teacher interactions (specifically students' relationships with teachers and their maths teacher's fairness) in secondary education had a significant association with attainment. These findings imply that one potential focal area for maths interventions could involve improving these relationships and interactions. However, it is important to note that it is also possible that children underachieving in maths have worse relationships with their teachers as a result of their poor performance i.e. where children have received harsh feedback, or have experienced unpleasant public evaluation of their low abilities, and consequently dislike their teachers.

Another key finding of this study was the negative association between school belonging in secondary education and maths attainment, which implies that high-achieving maths students may not feel particularly happy in their secondary school.

Based on this idea, secondary schools could potentially help students feel more comfortable in their surroundings by providing a warmer school climate and by making adolescents' educational environment a more positive place to be.

Overall, these findings provide insight into what aspects educational interventions could potentially focus on when aiming to improve maths attainment. Future research should focus on determining the causality of these associations to better understand how these factors affect attainment, and to identify the most effective methods to improve maths outcomes.

The application and interpretation of these findings are affected by methodological limitations that warrant further discussion. Firstly, this study aimed to focus on the effects of the transition to secondary education, comparing school-related factors across the transition to secondary education and how they may affect maths attainment trajectories. However, the timings of the measures used are not directly before and following transition, meaning that we cannot say with any certainty that the transition event itself had a direct impact on the outcomes. Additionally, the measures are not directly comparable pre- and post-transition meaning that we were unable to look at any changes over time in school-related affect, student-teacher relationships, and maths attitudes. Another weakness of the study was due to the availability of measures within the ALSPAC dataset. It was not possible to include several measures that have been linked to maths outcomes in previous studies (such as teachers' attitudes towards maths and their maths anxiety for example), or to include variables that were measured in both primary or secondary education (i.e. attitudes towards maths teacher). Including these predictors would have been useful in obtaining a more comprehensive model of

maths attainment trajectories, and by assessing the relative importance of different factors for attainment in primary and secondary education.

Despite the clear advantages of using a large birth cohort such as ALSPAC, including the large sample size and breadth of measures available, there are limitations to be considered relating to the generalisability of the findings. For example, adolescents within the ALSPAC sample have slightly higher grades than the population (Boyd et al., 2013). There was also very little bullying reported by parents of children in ALSPAC, which when compared to current figures for the rest of the UK (Ditch the label, 2019) suggests that the ALSPAC sample had relatively positive school experiences and peer-relationships. Future research would benefit from a more diverse sample as it could be that victimised children view their school-climate and student-teacher relationships differently compared to non-victimised children, thus experiencing different school-affect than those in this study.

Conclusion

Overall, of all the variables analysed here, this study found that the most important school-related predictor of maths attainment trajectories in primary and secondary education was children's maths attitudes. This effect was unsurprisingly strong with gains in attainment up to half a grade level at age 11, and around three-quarters of a grade level at age 14 when comparing children with the worst-rated maths attitudes to children with the best-rated maths attitudes. There were differences between primary and secondary variables where aspects of the school-climate (student-teacher relationships and school belonging) had a significant association with attainment in secondary education, but not in primary education. However, it cannot be determined

from this study alone whether the differences in the predictive power of variables in primary and secondary education were due to the transition event, structural differences between primary and secondary education, other age-related changes in development, or differences between measures used in the models. Due to methodological limitations and inconsistencies within the literature, the practical applications of the findings are reduced. However, it is apparent that schools should aim to emphasise and encourage positive student-teacher relationships (particularly in secondary education where opportunities for this is reduced), develop children's positive attitudes towards maths, and ensure teachers treat all students equally.

Chapter 6

Predicting maths anxiety from mathematical achievement across the transition from primary to secondary education

Chapter Prologue

In this final empirical chapter, I assess predictors of maths anxiety using data from the TEDS cohort. The transition event is associated with poor attainment (Akos et al., 2015; Alspaugh, 1998; Galton et al., 1999; Serbin et al., 2013) and increased emotional symptoms (Benner & Graham, 2009), and so this study aims to investigate whether the trajectories of maths attainment and emotional symptoms during the transitional period are associated with maths anxiety in early adulthood. This study is based on the ideas that emotional symptoms impair performance on maths tasks (Eysenck et al., 2007; Owens et al., 2012, 2014, 2008), and that maths anxiety is predicted by poor maths performance (Carey et al., 2016).

Abstract

The primary- to secondary-education transition is a substantive life event for many children. The transition can be associated with changes in the developmental trajectories of both emotional health and academic achievement. The current study looked at whether the trajectory of mathematical attainment and emotional health (anxiety) across this transition predicted later maths anxiety. A secondary analysis of data from the Twin Early Development Study (TEDS) was performed. The statistical models were fit on the 753 participants (one from each twin pair) for which there were measures of mathematical performance across the primary- to secondary-education transition and maths anxiety at age 18. Two multilevel growth models were fit predicting mathematical attainment and anxiety over the primary- to secondary-education transition. The intercepts and slopes for each child were extracted from these models and used as predictors of subsequent maths anxiety at age 18. These effects were adjusted for biological sex, socioeconomic status, verbal cognitive ability and general anxiety. Maths anxiety at age 18 was significantly predicted by both pre-transition levels of anxiety and mathematical attainment and their rate of change across the primary- to secondary-education transition. However, the effects were small suggesting that theories of maths anxiety may have overplayed the role of prior mathematical attainment and general anxiety.

Introduction

Poor maths achievement and abilities in childhood have far-reaching consequences leading well into adulthood (Maloney, 2016). Numeracy difficulties in childhood costs over 760 million per year to the public in the UK alone, with poor numeracy and literacy combined costing over 2.3 billion (Every Child a Chance Trust, 2009). Failing to address these problems early in development leads to greater unemployment, lower income, fewer promotions, school exclusions, substance misuse, depression, and criminal activity (Every Child a Chance Trust, 2009; Geary, 2011b; Parsons & Bynner, 1997). Poor maths skills further limit educational opportunities, for example, around 49% of working-age adults have the maths skills expected of primary-school children, with only 22% of working-age adults having the equivalent of a C-grade or above in GCSE maths, which is widely required for additional education courses in the UK (National Numeracy, 2018). The cost to the public, and the individuals affected (i.e. through poor health and low income) demonstrates the importance of understanding the causes of low achievement. Previous research has predominantly investigated underlying cognitive abilities (e.g. IQ, working memory, and processing speed), however recent research has reviewed and highlighted the importance of affect within the performance and development of maths abilities, particularly focusing on the effects of maths anxiety (e.g. Chang & Beilock, 2016; Dowker et al., 2016).

Maths anxiety is defined as fear, tension and discomfort which are felt by some individuals in situations involving mathematics, which may interfere with the performance of mathematical tasks (Ashcraft, 2002). Maths anxiety can elicit severe

emotional reactions to maths tasks (Ashcraft, 2002), and has similar symptoms to those that contribute to the diagnostic criteria of anxiety disorders. Despite a moderate correlation between maths anxiety and general anxiety, $r = 0.35$ (Ashcraft & Ridley, 2005), and despite partial aetiological overlap with other anxiety types (Malanchini et al., 2017), maths anxiety is widely recognised as a distinct construct (Hart et al., 2016).

The estimated prevalence of maths anxiety varies significantly across studies, partly due to differences in both measurement and the operationalization of diagnostic criteria (Dowker et al., 2016). Chinn reported estimates of 2-6% for high maths anxiety in secondary school pupils in the UK (Chinn, 2009). Similarly, a large study of 1,757 UK school children between years 4 (age 8-9) and 7 (age 12-13) found that 11% of children had an average score above ‘moderate anxiety’ on a maths anxiety scale (Devine, Hill, Carey, & Szűcs, 2018). Researchers investigating less severe levels of maths anxiety (mostly in students) have tended to report higher estimates, between 11% to 68% (Ashcraft & Moore, 2009; Betz, 1978; Johnston-Wilder, Brindley, & Dent, 2014; Richardson & Suinn, 1972). Regardless of the variability in these estimates, there are evidently substantial number of individuals experiencing varying levels of maths anxiety, and its corresponding negative impact.

Maths anxiety is not restricted to academic environments, it is experienced in and interferes with a wide range of everyday situations (Jansen, Schmitz, & Maas, 2016). It has been linked to poor financial planning (McKenna & Nickols, 1988), low self-efficacy in teachers (Swars, Daane, & Giesen, 2006), and poor drug calculations in nurses (McMullan, Jones, & Lea, 2012). In academic settings, maths anxiety is a barrier to learning related subjects such as statistics (Field, 2010, 2014), and is associated with

the avoidance of optional maths courses within education (Ashcraft, 2002), and the avoidance of maths and science, technology, engineering and maths (STEM) related careers (Ashcraft, 2002; Beilock & Maloney, 2015; Maloney, 2016). This avoidance of maths perpetuates a negative cycle. For example, people experiencing maths anxiety are more likely to avoid maths-related situations, leading to fewer opportunities to practice and develop their skills, resulting in worse performance later on and consequently greater levels of maths anxiety (Ashcraft, 2002).

A relationship between maths anxiety and poor maths performance has been consistently found in a range of studies (Ashcraft & Kirk, 2001; Ashcraft & Krause, 2007; Ashcraft & Moore, 2009; Dowker et al., 2016; Hembree, 1990; Ma, 1999; Ma & Xu, 2004; Wu, Amin, Barth, Malcarne, & Menon, 2012), and has been identified in children as young as 6 and 7 years old (Cargnelutti, Tomasetto, & Passolunghi, 2017; Ramirez, Gunderson, Levine, & Beilock, 2013). Two meta-analyses report the correlation between maths anxiety and maths performance to be between $r = -0.27$ to -0.36 in high school and college students (Hembree, 1990; Ma, 1999). The most recent meta-analysis reports the overall correlation as $r = -0.27 [-0.31, -0.23]$ in primary school children and $r = -0.36 [-0.40, -0.32]$ in secondary school children (Namkung, Peng, & Lin, 2019). Other studies have reported correlations of $r = -0.35$ in college students (Ashcraft & Kirk, 2001; Ashcraft & Krause, 2007), with evidence of a stronger relationship between high school grades and maths anxiety of $r = -0.67$ (Ashcraft & Kirk, 2001). Furthermore, maths anxiety is strongly related to maths enjoyment, $r = -0.75$, and the motivation to do well in maths, $r = -0.64$ (Hembree, 1990). These effects of anxiety are limited to maths performance with very little influence on verbal tasks (Dowker et al., 2016).

The detrimental relationship between maths anxiety and poor maths achievement is a universal problem. Results from the 2012 Programme for International Student Assessment (PISA) show that on average across participating Organisation for Economic Cooperation and Development (OECD) countries, higher maths anxiety is associated with a 34-point lower score (on average) in mathematics, reportedly the equivalent of almost one year of schooling (OECD, 2013). The same report suggests that the number of students experiencing maths anxiety increased slightly from 2003 to 2012, with the most significant increases for students in New Zealand, Sweden, Uruguay, Australia, Tunisia and Norway. The widespread effects of maths anxiety highlight the importance of research in this area. Children from various countries and cultures are struggling within their maths education, so much that they are potentially ‘losing’ a year or more of schooling - meaning early intervention is vital. However, the success of any potential intervention strategy relies heavily upon the current understanding of the underlying causes and issues associated with increased maths anxiety.

To sum up, maths anxiety is a widespread problem with far-reaching negative consequences for school leavers both in everyday life and if they pursue further education. As such, understanding what predicts maths anxiety is important to better inform attempts to mitigate those negative impacts. Logically, there are three plausible descriptions of the maths anxiety-maths performance relationship. First, maths anxiety could cause poorer maths performance by impairing the processing and retrieval of information and fostering avoidance (and therefore practice) of maths tasks. This possibility has been labelled the Debilitating Anxiety Model (Carey et al., 2016). Second, the reverse could be true: the Deficit Model describes the possibility that poor

maths performance leads to maths anxiety (Carey et al., 2016). The final possibility is that the relationship between maths anxiety and maths performance is bidirectional (the reciprocal model). Within this final model anxiety is seen to impair performance, but this poor performance is believed to increase anxiety in subsequent maths activities (Carey et al., 2016).

Dissociating the debilitating anxiety model from the deficit model hinges on demonstrating whether maths anxiety precedes poorer performance or vice versa. There is direct evidence that maths anxiety can predict poorer performance from studies that have manipulated anxiety levels and shown a corresponding change in subsequent maths performance (Faust, 1996; Park, Ramirez, & Beilock, 2014). There is also indirect evidence in that individuals experiencing maths anxiety are more likely to avoid maths tasks, which implies that maths anxiety leads to fewer opportunities to practice maths skills and, therefore, improve performance (Ashcraft, 2002; Hembree, 1990). However, there is also evidence that poorer performance can precede maths anxiety. For example, longitudinal studies have shown that the correlation between academic performance in one year and maths anxiety in the following year is stronger than the correlations between maths anxiety in one year and academic performance in the following year (Ma & Xu, 2004). On the basis that existing research cannot dissociate the debilitating anxiety model from the deficit model it is reasonable to assume that the reciprocal model is, at present, the most plausible description of the maths anxiety-maths performance relationship. Given that, the current study aims to look at predictors of maths anxiety at school-leaving age (18).

To date, several sources of maths anxiety have been identified including genetic and environmental factors (Chang & Beilock, 2016; Suárez-Pellicioni, Núñez-Peña, & Colomé, 2016). Genetic risk factors account for up to 40% of the variance in maths anxiety (Malanchini et al., 2017; Wang et al., 2014). The remaining variance will be explained by direct environmental influences and their interactions with genetic risk. For example, the expression of a genetic risk for maths anxiety is likely to be influenced by aspects of the home environment such as parental involvement (Vukovic, Roberts, & Green Wright, 2013), and the school environment, such as teachers' maths anxiety and its knock on effect on their mathematical and teaching ability (Beilock, Gunderson, Ramirez, & Levine, 2010). As already discussed, prior maths performance seems likely to predict future maths anxiety. Maths anxiety may stem from very early deficits in numerical abilities (Maloney, Ansari, & Fugelsang, 2011; Maloney, Risko, Ansari, & Fugelsang, 2010; Núñez-Peña & Suárez-Pellicioni, 2014) such that individuals with poor basic maths abilities when starting school are more likely to experience maths anxiety later on (Maloney & Beilock, 2012). The first hypothesis is, therefore, that early mathematical performance will predict maths anxiety at age 18 longitudinally. Also, the trajectory of a child's mathematical attainment should predict future maths anxiety: those with a slower rate of change in their mathematical attainment will have greater maths anxiety in the future.

As mentioned before, 60% of the variance in maths anxiety can be attributed to environmental influences and their interactions with genetic risk. These influences might act on maths anxiety through their influence on the child's mathematical attainment and learning trajectory, but also through their influence on the child's emotional well-being. It is likely that characteristics of the individual feed into both

maths anxiety and maths performance and are themselves influenced by the school environment and how it is perceived. Psychological theories such as the attentional control theory provide a plausible underlying mechanism through which anxiety impairs performance (Eysenck & Derakshan, 2011; Eysenck et al., 2007). The main assumption in this theory is that anxiety experienced in the moment (state anxiety) increases attentional allocation towards threat-related stimuli such as worrisome thoughts, resulting in less attention available for performance-based tasks. The system involved in allocating attention is the central executive and other executive functions including working memory, shifting, updating and inhibition (Baddeley, 2000; Miyake et al., 2000), which have been found to be particularly important in the development and performance of maths abilities (St Clair-Thompson & Gathercole, 2006). Additionally, maths is arguably more impaired by anxiety compared to other subjects because maths is particularly taxing on executive function skills (Cragg & Gilmore, 2014). For example, in mental arithmetic tasks individuals are required to utilise their working memory, as well as shifting and updating (Bull & Scerif, 2001; Espy et al., 2004) to be successful. Therefore, if the experience of anxiety takes up a large amount of the executive function allocation, less allocation is available for working memory, and the shifting and updating processes. Working memory has been found to correlate with maths anxiety (Ashcraft & Kirk, 2001) and performance is particularly impaired by maths anxiety on high working-memory load tasks (Ashcraft & Krause, 2007).

The effects of state anxiety on performance are moderated by an individual's dispositional tendency to experience anxiety (trait anxiety). The processing biases associated with state anxiety are activated at lower levels of 'threat' in individuals with high trait anxiety compared to those with low trait anxiety (Mathews & MacLeod,

2005). Put another way, the effects of state anxiety are exacerbated in those high on trait anxiety. As such, high levels of trait anxiety should predict maths anxiety but this relationship should be exacerbated by elevated levels of state anxiety. The school environment has the potential to create anxiety at school and this state anxiety, which has a knock-on effect on mathematical performance, will be heightened for trait anxious children. The current study focusses on one particularly stressful era in many children's educational journey: the transition from primary-to-secondary education.

The school environment is a large component of the child-specific environment, and during the primary-secondary education transition the school environment changes radically for many children (for a review see Evans et al., 2018). For example, in the UK, in primary school children typically experience a smaller, more personalised class taught by a single teacher and learning is task-oriented. In contrast, secondary schools typically have larger, more impersonal, classes taught by multiple teachers and learning is performance-focussed. This transition, when children leave their primary education institution to attend a typically separate secondary education institution usually between the ages of 10-14 years, is potentially highly influential in creating or exacerbating maths anxiety. The primary to secondary education transition is a normative event for most children that is widely recognised as one of the most stressful events young adolescents will experience (Chung et al., 1998; Coelho & Romão, 2016). It can elicit various negative academic, behavioural and emotional outcomes (Evans et al., 2018). The transition coincides with pubertal development in adolescents and is also a period where emotional disorders become more salient (Kessler et al., 2005). Increases in general anxiety and school concerns around the time of transition have also been widely reported (Akos et al., 2015; Arowosafe & Irvin, 1992; Harter et al., 1992; Lucey &

Reay, 2000; Rice et al., 2011). The transition is a potentially problematic time for young adolescents and the negative effects can be extensive. In addition to declines in general academic achievement (e.g. Akos et al., 2015; Gutman & Midgley, 2000), maths achievement is stifled during the transitioning year with around 34% of pupils making no progress in maths between primary and secondary education (Galton et al., 1999). Furthermore, interest, enjoyment, confidence, and self-efficacy in maths declines following the move to secondary school (e.g. Deieso & Fraser, 2019; Dotterer et al., 2009; Midgley et al., 1989a, 1989b). Maths anxiety has been found to increase at the time of the transition for students that moved to a new secondary school compared to those that did not, with greater increases reported for females and high-achievers (Madjar et al., 2018b). Additionally, Hill et al. (2016) found a significant association between high maths anxiety and low maths performance in secondary education students, but not for those in primary education. The secondary education pupils in their sample had recently transitioned to their new school, raising the question of whether the transition event itself impacted the relationship found between maths anxiety and maths achievement.

The present study

To sum up, there is likely to be a reciprocal relationship between maths anxiety and maths performance. Maths performance early in a child's academic is likely to predict future maths anxiety. Compared to children whose early performance is strong and whose educational trajectory over time follows the expected course, those with poorer early maths performance, or whose trajectory over time falls short of expectations, would be expected to experience more future maths anxiety. The

trajectory of a child's maths performance is likely to be affected by both the school environment, the individual characteristics of the child, and by the interplay between the two. With respect to the school environment the transition from primary-to-secondary education represents a significant change in the environment that has a negative impact on many children. In addition, the impact that it has is likely to be worse for children high on trait anxiety. Specifically, it might heighten or maintain high levels of trait anxiety. Therefore, trait anxiety before and after the transition from primary-to-secondary education should also predict future maths anxiety.

This study aims to predict maths anxiety longitudinally using a secondary analysis of the Twin Early Development Study (TEDS). It is hypothesised that poor maths achievement during the primary-secondary education transition will predict later maths anxiety. In addition, it is predicted that children experiencing increased emotional difficulties before the transition will be at a greater risk of a negative transition to secondary education, leading to a poorer maths trajectory across the transition and increased maths anxiety at age 18.

Method

Sample

This study was a secondary data analysis of the Twins Early Development Study (TEDS), a UK longitudinal twin registry that recruited from all families living in England and Wales who had twin-births between 1994 and 1996. The sample comprises four birth cohorts and the current analysis included participants recruited from the first two cohorts, aged between 18 and 21. The initial cohort comprised of 12,586 children,

but only 1,457 of those completed maths anxiety measures at age 18. Of these children, maths attainment information across the school transition was available for only 1,104. The purpose of the paper was not to produce genetically-informed models, therefore only one randomly-selected member of each twin contributed to the models. The sample is representative of the UK population (Haworth et al., 2013).

Measures

Maths anxiety at age 18.

Maths anxiety was assessed using a modified version of the Abbreviated Math Anxiety Scale, AMAS (Hopko, Mahadevan, Bare, & Hunt, 2003). The AMAS includes 9 descriptions of maths-related activities to which participants indicate their anxiety on a 5-point scale ranging from 1 = *not nervous at all* to 5 = *very nervous*. Some examples are ‘reading a maths book’ and ‘listening to a maths lecture’. Some items were modified to make the scale age appropriate (for details see Malanchini et al., 2017). The average response was used yielding a score that could range from 1 to 5. The AMAS has excellent internal validity, $\alpha = .90$ (Hopko et al., 2003). The modified AMAS used in the TEDS sample also has excellent internal validity, $\alpha = .94$, and test-retest reliability, $r = 0.85$ (Malanchini et al., 2017).

General anxiety at age 18.

General anxiety was measured using an online version of the 7-item Generalized Anxiety Disorder Scale, GAD-7, which is a validated and reliable measure of anxiety in the general population (Spitzer, Kroenke, Williams, & Löwe, 2006). For each of seven problems, participants rated how often they have been bothered by it in the past two weeks on a 4-point scale (1 = *not at all*, 4 = *nearly every day*). Example problems are: ‘not being able to control worrying’, ‘have trouble relaxing’, and ‘feeling afraid as if something awful might happen’. Responses are

scored from 0 to 3 resulting in a total score that can range from 0 to 21. The GAD-7 has good internal consistency, $\alpha = .89$ and test-retest reliability, $r = .64$, generally (Spitzer et al., 2006) and good internal consistency within the TEDS sample, $\alpha = .91$ (Malanchini et al., 2017).

Maths attainment. Maths achievement was measured pre- and post-transition to secondary education at ages 9 and 12 using teacher ratings based on the UK National Curriculum (NC) assessment guidelines followed by teachers within the UK state school system. Teachers were contacted in the second half of the school year to ensure they were knowledgeable about the child's maths performance. The scores were a composite of ratings of the following mathematical skills: using and applying mathematics; number and algebra; shape, space, and measures. Raw NC ratings can range from 1 to 9, but reflect age-related curriculum content so, for example, a child aged 9 is highly unlikely to have the relevant skills to be rated as a 9 (at this age a typical score would be 4). The National Curriculum assessments have been shown to be valid measures of academic achievement (Haworth et al., 2007; Kovas et al., 2007). Further information about the National Curriculum is available at <https://www.gov.uk/national-curriculum>.

Verbal attainment. Participants at age 10 and 12 were tested on a web-based adaptation of the WISC-III Multiple Choice Information (General Knowledge) and WISC-III Vocabulary Multiple Choice (Kaplan, Fein, Kramer, Delis, & Morris, 1999; Wechsler, 1991). The tests at age 12 were the same tests used at age 10 but with the addition of more difficult age-appropriate items. For a full description of the measures see (Haworth, Harlaar, et al., 2007), but in brief the Vocabulary Multiple-

Choice consisted of 30 vocabulary questions (e.g. what does “migrate” mean?) and the Multiple Choice Information contained 30 general knowledge questions (e.g. in which direction does the sun set?). For both scales children select one of three or four possible responses for each item. The scores were combined as the mean score standardized on a filtered sample in which all exclusions are removed using appropriate standardized web test scores. In the current sample, internal consistency is high for both vocabulary, $\alpha = .90$ (age 10) and $.88$ (age 12), and general knowledge, $\alpha = .87$ (age 10) and $.81$ (age 12) (Haworth, Harlaar, et al., 2007).

Anxiety across the school transition. General anxiety levels at ages 9 and 12 were assessed using the emotional symptoms subscales of the Strengths and Difficulties Questionnaire, (SDQ; Goodman, 2001, 1997). The SDQ contains 25 items that decompose into 5 factors, two of which broadly reflect externalizing symptoms (hyperactivity, conduct problems), two of which reflect internalising problems (emotional symptoms, peer problems) and one of which reflects prosocial behaviour. Anxiety levels across the school transition were indicated by the 5 items from the emotional symptoms subscale, which relate to symptoms of anxiety (e.g. “I worry a lot”, “I am nervous in new situations”, “I easily lose confidence”, “I have many fears I am easily scared”). Children responded to items using a response scale of *not true*, *quite true* and *very true*, scored as 0, 1 and 2 respectively. As such, the total score at each time point could range from 0 to 10. The SDQ has good concurrent and predictive validity (Goodman, 1997, 2001). In community samples the internal consistency for the self-report version of the scale overall is high, $\alpha = .80$, and for the emotional problems subscale is acceptable, $\alpha = .66$ (Goodman, 2001).

Socioeconomic status. Within TEDS, the mother's and father's highest educational qualification and job status were collected at first contact with the families (i.e. 18 months). The SES index used in the current study was the mean of 5 standardised SES ratings: mother and father qualification level, mother and father occupational status and the mum's age at the birth of their first child.

Data analysis plan

Analyses were conducted using R version 3.6.2 (R Core Team, 2017) and the following packages: *gmodels* (Warnes et al., 2018), *mice* (van Buuren & Groothuis-Oudshoorn, 2011), *MissMech* (Jamshidian, Jalal, & Jansen, 2014), *nlme* (Pinheiro, Bates, DebRoy, Sarkar, & R Core Team, 2019), and *tidyverse* (Wickham, 2017). In phase one, two multilevel models were fit to SDQ emotional symptoms and maths attainment scores respectively. Both models had the following general form:

$$Outcome_{ij} = [\gamma_{00} + \gamma_{10}Time_{ij}] + [\zeta_{0i} + \zeta_{1i}Time_{ij} + \epsilon_{ij}]$$

In other words, SDQ emotional symptoms or maths attainment were nested within participants at different timepoints (9 and 12 years old). The intercept and slope for the effect of time were modelled as random effects. Table 15 shows the model parameters for these two models. Having fitted each model, the individual intercept and slope for time for each child was saved into the data. This process resulted in four new variables being created. The first two represented the intercept for SDQ emotional symptoms and maths attainment (i.e. the values at age 9) and the remaining two represented the slopes of SDQ emotional symptoms and maths attainment over time (i.e. the change from 9 to 12 years old)

Table 15.

Key model parameters for multilevel growth models of maths attainment and SDQ over time.

| Effect | <i>b</i> | 95% CI | <i>t</i> | DF | <i>p</i> |
|-------------|----------|----------------|----------|----------|----------|
| Maths model | | | | | |
| Intercept | 2.93 | [2.90, 2.95] | 237.75 | 5,504.00 | 0.00 |
| Time | 0.48 | [0.47, 0.50] | 81.75 | 981.00 | 0.00 |
| SDQ model | | | | | |
| Intercept | 3.24 | [3.16, 3.32] | 80.67 | 6,217.00 | 0.00 |
| Time | -0.37 | [-0.39, -0.34] | -26.20 | 2,586.00 | 0.00 |

Note. SDQ = Strengths and Difficulties Questionnaire (anxiety subscale).

In phase two, the main model was simply a linear model predicting maths anxiety at age 18 from SES, biological sex, verbal attainment, general anxiety at age 18 and the four variables from the previous models: SDQ emotional symptoms (pre-transition), SDQ emotional symptoms (change), maths attainment (pre-transition), and maths attainment (change). All predictors were entered simultaneously. Table 16 shows the correlations between these variables.

Table 16.

Correlation matrix for variables in the models predicting maths anxiety (age 18).

| Variable | <i>M</i> | <i>SD</i> | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|----------------------------------|----------|-----------|----------|----------|----------|----------|---------|----------|---------|
| 1. Maths anxiety (age 18) | 2.28 | 1.00 | | | | | | | |
| 2. General anxiety (age 18) | 1.96 | 0.74 | 0.35*** | | | | | | |
| 3. SES | 0.32 | 0.95 | -0.07* | -0.05 | | | | | |
| 4. Maths (age 9) | 3.14 | 0.63 | -0.31*** | -0.09** | 0.28*** | | | | |
| 5. Maths (age 12) | 4.95 | 0.94 | -0.26*** | -0.08* | 0.29*** | 0.53*** | | | |
| 6. Verbal attainment (age 10-12) | 0.20 | 0.89 | -0.19*** | -0.11*** | 0.34*** | 0.42*** | 0.43*** | | |
| 7. SDQ anxiety (age 9) | 3.11 | 2.34 | 0.13*** | 0.17*** | -0.13*** | -0.15*** | -0.07 | -0.18*** | |
| 8. SDQ anxiety (age 12) | 2.07 | 2.02 | 0.24*** | 0.26*** | -0.10** | -0.15*** | -0.09* | -0.15*** | 0.40*** |

Note. SES = Socioeconomic status, SDQ = Strengths and Difficulties Questionnaire. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

The starting sample size for the final models was $N = 1,104$. Within this sample there were missing values across some of the predictors. There were 952 complete cases. Jamshidian and Jalal's nonparametric test of homogeneity of covariances was used to test whether data were missing completely at random (Jamshidian & Jalal, 2010). If covariances are comparable (i.e. the test is not significant) across groups with different patterns of missingness then MCAR can be assumed. The test was non-significant, .36, and the paternal data .36 giving no reason to reject the assumption that data are missing completely at random. Missing data were handled using multiple imputation implemented with the *mice* (van Buuren & Groothuis-Oudshoorn, 2011) package using predictive mean matching. Seventy imputation samples were created, and the final model was estimated by pooling the models fit to these samples (Enders, 2017; White et al., 2011).

Results

Table 17 shows summary statistics for all of the variables in the model. Scores on maths anxiety extended across the full range of the scale, but with a mean and median below the mid-point of the scale. SDQ emotional symptoms scores similarly covered the full range but were, on average, towards the low end with relatively high variance compared to the mean. Interestingly, emotional symptoms were lower post-transition compared to pre, indicating that anxiety had decreased. Maths performance increased from age 9 to 12 as would be expected based on how NC levels are scored.

Table 17.

Summary statistics for the key study measures.

| Measure | <i>n</i> | Min | Max | <i>Mdn</i> | <i>M</i> | 95% CI | <i>s</i> |
|-------------------------------|----------|-------|-------|------------|----------|--------------|----------|
| Maths anxiety (age 18) | 1104 | 1.00 | 5.00 | 2.00 | 2.28 | [2.22, 2.34] | 1.00 |
| General anxiety (age 18) | 1104 | 1.00 | 4.00 | 1.71 | 1.96 | [1.91, 2.00] | 0.54 |
| Maths (age 9) | 915 | 1.00 | 5.00 | 3.00 | 3.14 | [3.10, 3.18] | 0.40 |
| Maths (age 12) | 609 | 1.33 | 9.00 | 5.00 | 4.95 | [4.87, 5.02] | 0.88 |
| SDQ anxiety (age 9) | 1006 | 0.00 | 10.00 | 3.00 | 3.11 | [2.97, 3.26] | 5.46 |
| SDQ anxiety (age 12) | 1015 | 0.00 | 10.00 | 2.00 | 2.07 | [1.95, 2.19] | 4.09 |
| SES | 1063 | -2.21 | 2.55 | 0.27 | 0.32 | [0.26, 0.38] | 0.90 |
| Verbal attainment (age 10-12) | 1000 | -2.60 | 2.34 | 0.26 | 0.20 | [0.15, 0.26] | 0.79 |

Note. SES = Socioeconomic status, SDQ = Strengths and Difficulties Questionnaire.

Table 18.

Key model parameters for predictors of maths anxiety at age 18.

| Predictor | <i>b</i> | 95% CI | <i>t</i> | DF | <i>p</i> |
|------------------------------|----------|----------------|----------|----------|----------|
| Intercept | 3.19 | [2.77, 3.60] | 15.02 | 1,076.18 | 0.00 |
| SES | 0.04 | [-0.02, 0.10] | 1.40 | 985.64 | 0.16 |
| Biological sex | -0.37 | [-0.48, -0.26] | -6.45 | 1,090.74 | 0.00 |
| SDQ anxiety (pre-transition) | 0.06 | [0.03, 0.10] | 3.52 | 1,028.91 | 0.00 |
| SDQ anxiety (change) | 0.21 | [0.09, 0.33] | 3.56 | 1,024.95 | 0.00 |
| Verbal attainment | -0.01 | [-0.09, 0.06] | -0.40 | 750.33 | 0.69 |
| Maths (pre-transition) | -0.46 | [-0.57, -0.35] | -8.03 | 1,067.01 | 0.00 |
| Maths (change) | -0.32 | [-0.64, 0.00] | -1.96 | 1,090.87 | 0.05 |
| General anxiety (age 18) | 0.36 | [0.28, 0.43] | 9.42 | 1,088.99 | 0.00 |

Note. SES = Socioeconomic status, SDQ = Strengths and Difficulties Questionnaire.

Table 18 shows the model parameters for predictors of maths anxiety at age 18. With respect to statistical significance, biological sex, SDQ emotional symptoms (pre-transition), the change in SDQ emotional symptoms, maths attainment (pre-transition), the change in maths performance across the transition, and general anxiety at age 18 all significantly predicted maths anxiety. Bearing in mind that maths anxiety could range from 1 to 5, males were 0.37 points lower on this scale than females, and a point increase on the general anxiety scale (which ranged from 1 to 4) equated to a 0.36 increase in maths anxiety. With respect to the substantive predictors, a unit change in maths attainment pre-transition (at age 9 measured on a 5-point scale) equated to a 0.46 unit decrease in maths anxiety 8 years later at age 18. A unit increase in the rate of change (i.e. the slope) in maths attainment across the transition equated to a -0.32 decrease in maths anxiety at age 18. To unpick what this value means, first let us look at what a typical change in maths attainment would be across the school transition. In our earlier model we operationalized the primary-to secondary education transition as the 3-year period between ages 9 and 12 and found that maths attainment increases at a rate of 0.48 units per year (Table 15). A typical change in maths attainment across three years during which the school transition occurs would be $3 \times 0.48 = 1.44$ units. Imagine a child who shows no improvement in their maths ability over the same three years. Their slope for attainment will be 0, and it will be 1.44 units lower than a typical child. Their predicted maths anxiety at age 18 will correspondingly be $-1.44 \times -0.32 = 0.46$ higher on the 5-point maths anxiety scale than the average child. Put another way, the rate of change in maths attainment had a small effect on maths anxiety at age 18.

With respect to SDQ emotional symptoms, a unit change in pre-transition scores (at age 9 and measured on a 10-point scale) equated to a 0.06 unit increase in maths anxiety at age 18. To place this effect in perspective, a change equating to the entire length of the SDQ emotional symptoms scale predicts only a 0.63 increase in maths anxiety.

A unit increase in the change in SDQ emotional symptoms across the school transition equated to 0.21 unit increase in maths anxiety. The typical change in SDQ emotional symptoms across transition was a change of -0.37 units per year (i.e. anxiety decreased), or a $3 \times -0.37 = -1.11$ unit change across the three-year school transition. Therefore, a decrease in SDQ emotional symptoms across the school transition that is typical in magnitude would equate to a change in maths anxiety of $-1.11 \times 0.21 = -0.23$ units on a 5-point scale. Again, a small reduction.

Table 19 shows an unplanned, *post hoc*, model that quantifies the degree to which biological sex moderated the effects on maths anxiety of maths attainment and SDQ emotional symptoms prior-to and across the school transition. Biological sex did not significantly moderate any of the effects of maths attainment of emotional symptoms on subsequent maths anxiety.

Table 19.

Key model parameters for predictors of maths anxiety at age 18 (exploratory model).

| Predictor | <i>b</i> | 95% CI | <i>t</i> | DF | <i>p</i> |
|------------------------------|----------|----------------|----------|----------|----------|
| Intercept | 3.41 | [2.90, 3.92] | 13.19 | 1,074.58 | 0.00 |
| SES | 0.04 | [−0.02, 0.10] | 1.38 | 979.77 | 0.17 |
| Biological sex | -0.95 | [−1.71, −0.19] | -2.46 | 1,086.29 | 0.01 |
| SDQ anxiety (pre-transition) | 0.08 | [0.03, 0.12] | 3.58 | 1,009.39 | 0.00 |
| SDQ anxiety (change) | 0.24 | [0.10, 0.38] | 3.36 | 1,008.82 | 0.00 |
| Verbal attainment | -0.01 | [−0.09, 0.06] | -0.38 | 751.89 | 0.70 |
| Maths (pre-transition) | -0.52 | [−0.67, −0.38] | -7.14 | 1,070.35 | 0.00 |
| Maths (change) | -0.44 | [−0.85, −0.02] | -2.08 | 1,087.44 | 0.04 |
| General anxiety (age 18) | 0.36 | [0.28, 0.43] | 9.43 | 1,084.84 | 0.00 |
| Sex × Maths (pre-transition) | 0.16 | [−0.05, 0.37] | 1.52 | 1,088.13 | 0.13 |
| Sex × Maths (change) | 0.34 | [−0.32, 0.99] | 1.02 | 1,088.02 | 0.31 |
| Sex × SDQ (pre-transition) | -0.05 | [−0.12, 0.02] | -1.31 | 1,064.05 | 0.19 |
| Sex × SDQ (change) | -0.11 | [−0.35, 0.14] | -0.86 | 1,067.53 | 0.39 |

Note. SES = Socioeconomic status, SDQ = Strengths and Difficulties Questionnaire (anxiety subscale).

Discussion

This study shows that maths anxiety at age 18 was significantly predicted by biological sex and general anxiety (at age 18) but, most important, by maths attainment at age 9 prior to the transition to secondary education and by the change in maths attainment across that transition; and also both by anxiety symptoms on the SDQ prior to transition (also at age 9) and the change in anxiety symptoms across the transition.

The small effect of biological sex on maths anxiety at age 18 (males were 0.37 points lower on the maths anxiety scale) replicates the findings of previous research (e.g. Dowker et al., 2016; Devine, Fawcett, Szűcs, & Dowker, 2012; Madjar et al., 2018b), suggesting that females experience increased maths anxiety throughout adolescence and adulthood. One proposed explanation is that females show higher levels of trait anxiety (McLean & Anderson, 2009) and as a consequence the effects of state anxiety are exacerbated (Mathews & MacLeod, 2005). However, general anxiety was controlled for in the model, implying that sex differences in maths anxiety may develop from other aspects not investigated by the present study, such as stereotype threat (Maloney, Schaeffer, & Beilock, 2013) or a male advantage in maths performance at that age. As expected, greater general anxiety was found to predict increased maths anxiety at age 18 (a 1-point increase in general anxiety equated to a 0.36 increase in maths anxiety), consistent with wider literature (e.g. Hembree, 1990) suggesting that general anxiety and maths anxiety share genetic and environmental risk factors (Ashcraft & Ridley, 2005; Dowker et al., 2016; Malanchini et al., 2017; Wang et al., 2014).

The findings of this study also show that maths attainment pre-transition (at age 9), and the rate of change across the transition significantly predicted maths anxiety at age 18. For maths attainment pre-transition, 1 unit increase in attainment equated to a -0.46 unit change in maths anxiety, showing a moderate effect on maths anxiety at age 18. For the rate of change in maths attainment, a unit change in the slope of maths attainment equated to a -0.32 change in maths anxiety, which is a very small effect. Nonetheless, small though the effect is, it is consistent with the wider literature (Dowker et al., 2016; Hembree, 1990; Ma & Xu, 2004; Maloney et al., 2011, 2010; Núñez-Peña & Suárez-Pellicioni, 2014; Wu et al., 2012). In this sense, the results support the hypothesis from the reciprocal and deficit models of maths anxiety that poor performance leads to increased maths anxiety, but also imply that this relationship is very weak. However, as maths anxiety was not assessed during the transition period (age 9-12), the current study says nothing about whether this relationship is reciprocal. Nevertheless, the rate of change in attainment significantly predicted maths anxiety (albeit a small effect), implying that those who do not transition successfully in terms of attainment, are more likely to experience negative outcomes several years later, even when adjusting for general anxiety. Ultimately, the small effect implies that there are other processes or mechanisms underlying the association that we did not explore in this study, including motivation, and interactions between motivation and anxiety. The genetic and environmental factors underlying these unexplored mechanisms may be the same or partly the same as those underlying the predictors that we did explore, but we cannot test this idea here.

The other main finding of this study was that greater anxiety symptoms pre-transition (age 9) as measured by the SDQ significantly predicted increased maths

anxiety at age 18 ($b = 0.06$). The rate of change in anxiety symptoms also significantly predicted maths anxiety ($b = 0.21$), though when placing the size of the rate of change within the context of the typical change in anxiety seen between the ages of 9 and 12, the effect on maths anxiety at age 18 was very small (the change in maths anxiety equating to the typical change in anxiety symptoms was about a -0.23 shift on a 5-point scale). Because general anxiety at age 18 was adjusted for in the model, the effects of anxiety symptoms prior to and across the transition are unique to maths anxiety and not just predictors of general worries and anxiety symptoms. These findings support previous research that show correlations between general anxiety symptoms and maths anxiety (Hembree, 1990; Hill et al., 2016; Wang et al., 2014), but shows that early anxiety significantly predicts future maths anxiety. The size of the effect found in previous studies has been much greater than that found in this study (e.g. Hembree, 1990; Hill et al., 2016), but this could be explained by previous studies being cross-sectional, rather than looking at anxiety predicting maths anxiety some years later.

Overall, the findings suggest that a transition to secondary education characterised by poorer attainment and increased anxiety, both prior to- and across the transition, has small but long-lasting consequences leading into adulthood. The secondary education environment is viewed as creating greater competitiveness and social comparisons between students which can elicit maths anxiety in children (Carey et al., 2019; Evans et al., 2018). Combined with slower rates of attainment, and increased emotional difficulties during this time, students' self-confidence and self-efficacy could be easily negatively impacted, potentially creating the 'ideal' environment for maths anxiety to develop. While some researchers have found children as young as 6- and 7-years-old have maths anxiety (Cargnelutti et al., 2017; Ramirez et

al., 2013), it is possible that the transition to adolescence contributes to this process, given the changes in the learning environment, and the increasing difficulty of school work. The detrimental effect of high maths anxiety on careers, further study, and general well-being as discussed previously, highlights the need to focus on this period in adolescence in terms of intervention strategies. However, the effects of emotional difficulties and maths attainment during this period were small implying that the focus of future work should be broader than these variables alone.

Currently, schools employ various intervention strategies for children moving from primary to secondary education, which differ between institutions, and focus on improving self-confidence and problem-solving (e.g. Shepherd & Roker, 2005). However, the small size of the effects also raises the question of whether it is beneficial to focus on improving attainment and reducing anxiety across the transition, *solely* with the goal to reduce maths anxiety later on, or whether there are more effective ways to decrease maths anxiety with larger gain.

There are several methodological limitations in the present study. Anxiety symptoms prior to- and across the transition were generally low, meaning that the findings here may lack generalisability to individuals experiencing greater anxiety symptoms during pre-adolescence, or those having an extremely poor transition to secondary education in terms of emotional well-being. In addition, although the transition to secondary education is characterised by increased anxiety at the group level, in the current sample anxiety actually decreased during this period. This pattern of general anxiety may well explain why its effects on future maths anxiety were small. Perhaps this sample is atypical and future work might fruitfully look at samples from

communities where the school transition is particularly problematic. Also, maths anxiety was not measured across the transition from primary to secondary education, meaning that it was not possible to adjust predictors for prior levels of maths anxiety during the transition, or look at any changes in trajectory when moving to secondary education to see if emotional and attainment issues during this period exacerbated maths anxiety itself. Finally, although the measure of maths attainment derived from teachers were based on the National Curriculum examination benchmarks, they nevertheless reflect subjective ratings of the children's ability and are not as objective as, for example, National Curriculum exam scores.

Conclusion

Overall, the findings suggest that children experiencing greater emotional difficulties and poor maths attainment prior to the transition to secondary education are more at-risk of having higher maths anxiety at age 18. Furthermore, decreasing emotional difficulties and increasing attainment across the transition predicts lower maths anxiety at age 18. Given the small size of the effects, it is evident that there are other aspects that contribute to maths anxiety which should be the focus of future research. Nevertheless, transition strategies should remain focused on improving academic attainment (especially for female students) and emotional well-being and be aware of the effects of a successful transition to secondary education on maths anxiety later in adulthood.

Chapter 7

General discussion

In response to the reported ‘maths crisis’ in the UK (Carey et al., 2019), this thesis aimed to investigate predictors of maths attainment and maths anxiety around the transition from primary to secondary education. To recap, I examined the following research questions:

- What is the impact of the primary to secondary education transition on academic and psychological outcomes?
- How does working memory capacity and internalising symptoms contribute to maths attainment trajectories?
- In what ways do parents and the home environment affect maths attainment trajectories?
- Which school-related factors are the most important for maths attainment trajectories in primary and secondary education?
- Are emotional difficulties and maths under-attainment around the transition to secondary education key factors in the development of maths anxiety?

Because an extensive discussion is already present in each of the earlier chapters, the aim of this final chapter is to summarise and integrate the overall findings of this thesis, discuss the limitations of this project, provide recommendations for future research and suggest practical applications of the findings for educational intervention strategies.

Summary of the main findings

Chapter 2 reviewed the literature relating to the impacts of the transition from primary to secondary education with the purpose of integrating research findings and

evaluating the effects associated with the transition. In this chapter, a ‘successful’ transition was defined as emotional functioning and academic performance (Hall & DiPerna, 2017), and correspondingly, these constructs were the two main themes identified in the wider literature on the impacts of the transition. Within these themes, both individual-level and environmental-level effects were found, relating to social, learning, and academic aspects, and the home- and school-environment.

When looking at the effects on academic achievement generally, the key findings were that progress is particularly disrupted and attainment declines during the transitionary year. Some studies report declines in other education-related outcomes such as academic self-concept and self-perceptions, and attitudes towards maths and science across the transition between primary and secondary education. The number of studies on the interacting effects of contextual factors was particularly low, but of those available, the findings pointed towards SES, gender, cognitive abilities, and emotional functioning as potentially influential in altering academic outcomes following the transition.

Studies looking at the psychological effects associated with the transition typically focused on two ‘clusters’ of symptoms and behaviours considered to be internalising (i.e. anxiety and depression) or externalising (i.e. conduct problems and hyperactivity). The findings generally showed that children experiencing increased internalising, externalising symptoms and general concerns prior to the transition had poorer outcomes post-transition. There was also evidence of decreases in self-esteem and life satisfaction across this period. Contextual predictors found to alter the

psychological effects of the transition included gender and special educational needs (SEN).

Generally, the overall findings of the review were quite inconsistent. Some researchers found negative effects on psychological and academic outcomes stemming from the transition and others found positive or ‘neutral’ results. These inconsistencies found in the literature could be from methodological differences with some studies only including post-transition variables for example, there were also many differences in sampling and analytical strategies between studies such as the inclusion of additional predictors known to affect the outcome of investigation (i.e. gender, SES and SEN). In addition to those mentioned previously, there are many other interacting factors that further affect transition outcomes and ‘success’ such as children’s social support and school affect in adolescence, which were considered by only a small number of studies.

Overall, this chapter adds to existing knowledge by integrating the research findings and identifying key issues surrounding the transition event. Although, it was particularly clear from the review that our understanding of the many factors that affect transition success is particularly poor. The methodological limitations present within the wider research makes it difficult to draw clear, definitive conclusions from the findings. These inconsistencies demonstrate the need for further research investigating outcomes surrounding the transition. As will be discussed further in the following sections, the findings of the empirical chapters did not provide support for the conceptual framework generated from the literature review in that the transition did not appear to be substantially detrimental to maths attainment in these studies as reported in the wider literature.

Chapters 3-5 aimed to lessen the gap in knowledge that was identified by the review (Chapter 2) by examining how cognitive, emotional, parental, home- and school-environment factors might contribute to maths attainment trajectories across the transition from primary to secondary education. All three chapters used latent growth models of data from participants in the ALSPAC cohort, looking at associations between the aforementioned predictors and maths attainment trajectories. The latent growth models in Chapters 3 and 4 looked at maths attainment at age 11, and the growth in maths attainment over time. In Chapter 5, two latent growth models looked at maths attainment at age 11 and age 14 separately, and the growth in maths attainment over time. The key findings from each of these chapters are now discussed in greater detail.

Following the PET as a theoretical framework (Eysenck & Calvo, 1992), Chapter 3 specifically focused on the associations between working memory, internalising symptoms, the interaction between them, and maths attainment trajectories. Prior research had examined the effects of working memory capacity and anxiety (Owens et al., 2012, 2014, 2008) based on the idea that anxiety consumes cognitive resources as proposed by the PET, which are required for successful performance on maths tasks. Previous research had investigated this relationship in small-scale studies, little was known of the potential long-term effects and whether this association was present for internalising symptoms generally rather than for anxiety exclusively. The study found weak associations between increased working memory capacity, decreased internalising symptoms, and increased maths attainment trajectories (at age 11 and a greater rate of change over time). The analysis did not reveal a statistically significant interaction between working memory and internalising symptoms, which did not support the original hypothesis and existing literature. The findings of this study build

upon existing knowledge by showing that working memory capacity and internalising symptoms in childhood are associated with maths attainment longitudinally, however, the effect of internalising symptoms on attainment was not moderated by working memory capacity suggesting that the PET framework only applies to anxiety and not other internalising symptoms and behaviours. Contextual predictors were included in the model to adjust for their effects. The statistically significant predictors were sex, SES, IQ, and parental education qualifications. As anticipated, higher SES and child IQ were associated with increased maths attainment (which was replicated in all three chapters). Males were also found to have slightly higher attainment at age 11. However, an interesting finding of the analysis was that parental education had an especially strong association with maths attainment. This effect was not surprising, however, the size of the effect meant that the gains in attainment between children to parents whose highest qualification was a CSE or below compared to those whose parents had at least one degree between them was substantial - the difference between these groups was almost the equivalent of a year's worth of progress by age 11. Moreover, because SES and IQ were included in the model, the associations between parental education and attainment were adjusted for these effects meaning that we cannot reduce this association to higher family socioeconomic status or greater offspring intelligence that is usually associated with greater parental education.

The literature reviewed in Chapter 2 demonstrates that the transition is particularly anxiety-inducing, whereas, in this study the mean level of internalising symptoms was especially low with very few children experiencing substantial emotional difficulties prior to the transition. Contradictory to the review, it is apparent from this study that the negative psychological effects associated with the transition and the

effects on attainment are not as strong as originally thought. Instead, it seems that contextual factors that are largely stable across the transition (i.e. SES, IQ, and parental education) are stronger predictors of maths attainment during this time.

Based on the aforementioned findings relating to parental education qualifications, the purpose of Chapter 4 was to further understand this relationship by attempting to uncover the associations between parental- and home-factors and maths attainment trajectories. This chapter investigated early home-teaching, parental mental health, parent-child home interactions, parent-child relationships, parental school involvement, child gendered play, and parental education qualifications. Using a latent growth model, the analysis revealed significant (and practically substantial) associations between maths attainment (at age 11 and the rate of change over time) and parent-child harmony, parental involvement in school at age 11 and parental education qualifications (as reported in Chapter 3). The findings showed that children's attainment is greater when parents participate in additional school activities and when they have more positive relationships with their children. These results are not unexpected but add to existing knowledge (e.g. Rice et al., 2015) by further demonstrating the importance of parents during the education transition process.

In support of these findings, social support was one of the areas identified in the review in Chapter 2 as influential for the success of a transition, and parents are a substantial proportion of this network. When relating this study back to the conceptual framework proposed in Chapter 2, the findings also support the inclusion of children's social schema and home environment as factors predicting a successful transition. For example, children with more positive home and social environments (i.e. with more

involved parents and better parent-child relationships), had better academic adjustment to secondary school. Other possible explanations for these findings could also be that parents who are more involved within their children's education are more aware of their changing developmental needs (Eccles et al., 1993) or are more aware of the work their children are doing in school and are more able to assist with homework or further develop their learning in other ways.

However, it was particularly surprising that the other parental factors included in the analysis were not significant predictors of maths attainment. Based on the findings of previous studies (predominantly conducted in the US and Canada e.g. Skwarchuk et al., 2014; Huntsinger et al., 2016), it was expected that home-teaching would have a stronger association with maths attainment, and poor parental mental health would have a greater impact. As will be discussed further in the limitations section, this is likely due to the lack of depth in the measures used in analysis, and highlights areas for future research.

Chapter 5 was the final study using the ALSPAC cohort and focused on factors relating to the school environment, student-teacher interactions, and maths-related affect. Many of the changes children experience over the transition stem from the school environment - in primary education children attend smaller schools, with one classroom and teacher for the entire academic year, and hold close student-teacher relationships. Whereas, in secondary education, schools are considerably larger, students are required to change classes for different subjects and have specialist teachers for different classes. Due to the number of physical differences between primary and secondary education, two growth models investigated school-related factors in primary and secondary

education separately which aimed to investigate possible predictors of maths attainment relating to primary and secondary education environments.

In the primary education model, the only statistically significant predictor (excluding contextual variables) were attitudes towards maths whereby more positive attitudes were associated with increased maths attainment at age 11 and an increased rate of change. Similarly, in the secondary education model, positive attitudes towards maths were strongly associated with attainment at age 14 and with an increased rate of change over time. Other statistically significant predictors of increased maths attainment in the secondary education model included positive student-teacher relationships, and perceived maths teacher fairness. These findings showed that adolescents who perceived their relationships with their secondary school teachers as positive, and those that felt their maths teachers treated all students equally had greater maths attainment and imply that the role of secondary education teachers is particularly important for long-term maths outcomes. School belonging in secondary education was negatively associated with attainment where greater school belonging was associated with decreased attainment at age 14 and a slower rate of change, suggesting that high-achievers in maths may not feel particularly comfortable at school, though further research is needed to examine this possibility. Because of the limitations regarding the measures used, it was not possible to assess any changes in the variables over time which would have been useful given the differences found between the primary and secondary model (i.e. the importance of student-teacher relationships in secondary education but not in primary education). However, this provides suggestions for future research opportunities.

These findings together provide further support for the role of children's social and learning schemas as identified in Chapter 2. Particularly, children's enjoyment and interest in academic domains, and their relationships with teachers are influential for their adjustment to secondary education and their academic outcomes. However, it is evident from the results that children's social schema is potentially more important in secondary education as a significant association between maths attainment and student-teacher relations and school aspects was only found in secondary education and not in primary education.

The final empirical chapter of this thesis examined the primary to secondary education transitional period as a critical timepoint for the development of maths anxiety. This study investigated the trajectories of maths attainment and emotional symptoms across the transition and assessed whether they were linked to maths anxiety in early adulthood using a linear model of the TEDS cohort. Two multi-level growth models were fit to the data to extract children's trajectories of maths attainment and emotional symptoms in early adolescence. These measures were included in a linear model of the TEDS data along with measures of general anxiety, sex, SES, and verbal cognitive ability. The findings showed that low maths attainment and heightened emotional symptoms pre-transition were associated with maths anxiety at age 18. Additionally, a slow rate of change for maths attainment and an increasing rate of change for emotional symptoms across the transitional years were associated with increased maths anxiety at age 18. These results imply that the transition period is influential for later maths-related affect, especially where children are failing to make the expected progress in maths and are experiencing increased emotional symptoms. This study adds to the literature by identifying risk factors in early adolescence for the

development of maths anxiety in adulthood and highlights potential opportunity for maths interventions. However, the size of the effects were small, suggesting that the long-term effects on maths anxiety are not as substantial as anticipated. The findings also contradict the literature reviewed in Chapter 2, whereby most studies reported a negative impact of the transition for psychological wellbeing. In this study at the group-level, children's emotional symptoms were lower post-transition meaning that emotional symptoms had in fact declined across the transitional period. This finding suggests that the negative effects of the transition may not be as detrimental to wellbeing as once thought.

Overall, the key findings demonstrate that the transition is linked predominantly to negative psychological and academic outcomes, with poor maths attainment and increased emotional symptoms during this period associated with maths anxiety in adulthood. In addition, several cognitive, emotional, parental, and school factors were found to be associated with maths attainment trajectories throughout childhood and adolescence, and in the following, I discuss some of the potential applications of these findings further.

Applications of the findings to transition strategies

The findings of this thesis can be applied to help inform transition strategies employed by schools using research-based evidence. Currently, transition strategies are free to vary between schools and encompass a variety of activities which typically involve open days prior to the start of the first school term where students tour the school and meet with teachers and other children (Evangelou et al., 2008). Often, children have multiple visits to their new school and some children are assigned an

older student as a mentor (Evangelou et al., 2008). There is considerable variation between transition strategies but often the focus is on the practicalities of the move such as giving tours of the school so that children are more familiar with their environment and are less likely to become lost or fear being lost. These inconsistencies among strategy use mean that the transition experience differs for children moving to different secondary schools.

Within this thesis, several factors affecting the trajectory of children's maths attainment were identified, with varying magnitude on maths outcomes - the potential application of some of these key findings for transition strategies will now be discussed in further detail.

Firstly, working memory was found to weakly predict maths attainment, and given the small size of the effect, it is unlikely to be effective in administering interventions that solely focus on improving working memory capacity to improve maths performance (though one intervention has been shown to somewhat increase maths attainment for children not eligible for free school meals; Wright et al., 2019). The second key predictor identified was internalising symptoms, and again, this effect was small for both maths attainment (in Chapter 3) and maths anxiety (in Chapter 6). Improving children's emotional wellbeing would likely improve other outcomes unrelated to education such as children's social functioning and interpersonal relationships, and trials have shown promising results in earlier education transitions (Pophillat et al., 2016). However, the associated benefits would likely be very small for secondary education, and in terms of increasing maths attainment, it appears that focusing on improving internalising symptoms or working memory would have little

impact overall and it is perhaps more effective to focus on parental factors as discussed in greater detail below.

Other viable interventions could focus on factors within the secondary education environment, specifically, on facilitating positive student-teacher relationships. In Chapter 5, I found evidence for child-perceived maths teacher fairness and positive student-teacher relationships in secondary education as factors associated with increased maths attainment, and so implementing interventions focusing on improving student-teacher relationships and the interactions between teachers and students could be influential in improving attainment long-term. However, it is important to highlight that in secondary education children move between different classrooms and have different teachers for each subject meaning that they have fewer opportunities to interact with their teachers and build strong bonds. In addition, there is a higher performance-based goal orientation found in secondary education (Madjar et al., 2018a) and classes tend to be ability-grouped (i.e. in ‘sets’) which could further influence the perceived fairness of teachers based on children’s abilities.

In addition, it is difficult to make specific recommendations for transition strategies based on these two findings as the variables were measured at age 14, rather than during the transitional process at age 11-12. However, other researchers also highlight the need for positive student-teacher interactions during this time, and it is suggested that teachers could improve student relationships through increasing one-on-one contact, providing positive praise, and a warm classroom climate for example (Rice et al., 2015).

It is clear that focusing on facilitating positive student-teacher relationships throughout secondary education and ensuring teacher fairness in class would benefit maths attainment. It is also arguably easier to implement teacher-based strategies within schools that focus on improving student relations and fair teaching as opposed to attempting to increase working memory capacity and reduce internalising symptoms for *all* students. However, further research is needed to evaluate the most effective ways to administer teacher-focused transition strategies with the focus on maths outcomes.

Improving maths attitudes may also be one opportunity to help improve maths attainment outcomes in adolescence. In Chapter 5, the results showed that positive attitudes towards maths in primary and secondary education were associated with increased attainment at age 11 and age 14 respectively and were associated with an increased rate of change over time. It is apparent from these results that interventions focusing on improving attitudes towards maths may be beneficial, however, causality could not be established in the study and it is possible that increased maths attainment improves children's attitudes towards maths, as opposed to children's attitudes improving their attainment. Based on this reason, more research is needed to further understand the directionality of this relationship before interventions can be administered and evaluated.

The final potential avenue for transition strategies stemming from the findings of this research is to focus on children's parents. All of the studies using ALSPAC data (Chapters 3-5) found support for increased parental education as being associated with increased maths attainment trajectories. We failed to fully uncover the underlying reasons why parental education was so strongly associated with attainment (especially

given that IQ and SES were adjusted for in all of the models), which further research would need to address before focusing on parent-centred transition strategies. However, from the findings presented in Chapter 4, it is evident that parental involvement in school has some positive association with attainment. This finding implies that an improvement in maths attainment may be possible by increasing parents' participation in school activities. Though it is important to note that these findings do not imply causality. It is possible that parents highly involved in activities in school also participate in educational activities at home and hold positive attitudes towards the value of education themselves which are transmitted to their children. In addition, the effect was only significant when parents' involvement was measured just prior to the transition and not at an earlier age (i.e. at 8 years old), suggesting that the transition period is particularly important and that parental involvement potentially buffers against negative outcomes following the move. Further research would be needed to evaluate the effect of an intervention centred around parental involvement in a wide range of educational activities in school, and not just those covered by the measure used in these studies.

These recommendations are not exhaustive and merely highlight the potential focal areas for transition strategies in the future. More work would be needed to assess the effectiveness of any strategy generated based upon these findings and whether they are appropriate and effective for students excluded from the analyses in this thesis or those less represented in the sample (such as children with SEN and lower SES).

Limitations and future research directions

The empirical chapters of this thesis all used longitudinal analysis of secondary data which has both strengths and weaknesses. The large sample size in both cohorts allows for greater statistical power, but high levels of missing data were present which can bias results. Another strength is the broad range of measures available in the ALSPAC and TEDS cohorts, although, this means that in-depth measures of psychological phenomena are sacrificed for more shallow measures that focus on a wider range of constructs and topics. The timing of the assessments and dissemination of questionnaires is also somewhat unfavourable where key periods in development over the transition are missed. This limitation is particularly apparent when investigating the transitional period from primary to secondary education as many of the variables were not measured directly prior to, and following the transition meaning that the many changes occurring during this period were not captured in the analyses.

The characteristics of the ALSPAC and TEDS cohorts also affect generalisability. Participants in ALSPAC are more likely to be white, are less likely to be eligible for free school meals (an indicator of SES) and have higher educational attainment at age 16 (Boyd et al., 2013). Children in the TEDS sample have parents who are more highly educated, and more children have mothers not in employment when compared to the wider population (Haworth et al., 2013). TEDS additionally utilises the twin-study design which is most commonly used in genetic research. Only one child from each twin-pair was used for analysis as the aim was not to produce genetically informed models, however, there are characteristics specifically associated with being a twin that have been linked to intelligence (Ronalds, De Stavola, & Leon, 2005),

although, other research does not support this association with similar academic performance found for twins and singletons (Christensen et al., 2006). Additional cohort effects are also likely to be present (especially in the ALSPAC sample where the participants are now around 30 years old), for example the different usage of technology and social media in adolescence compared to children today, which further affects the generalisability and applicability of the findings.

One final limitation of this thesis was the focus on typically developing children and maths attainment within the typical developmental range. Children with special educational needs such as learning difficulties, physical disabilities, emotional and behavioural difficulties, and speech and language difficulties were excluded from analyses because of the high heterogeneity within this group, and the ensuing effects on model fit. This exclusion of children with SEN limits the application and generalisability of the findings from the empirical chapters of this thesis to children with additional needs or disabilities for several reasons. It is evident from reviews of the literature (Hughes et al., 2013) that children with SEN have different transition experiences compared to their peers. There are additional concerns children with SEN have compared to typically-developing children which are often exacerbated following the transition to the new secondary education such as mobility issues (when moving between multiple classes throughout the school day), speech difficulties (when communicating with friends and new teachers), and other health concerns (i.e. ensuring all teachers have access to necessary medical equipment if/when required).

The studies presented in this thesis focused on attainment within the typical developmental range as measured by national curriculum levels and so did not examine

the ways in which individuals with dyscalculia (defined as a specific learning disability affecting the normal acquisition of maths skills, despite individuals' cognitive abilities being typical for their age; Shalev, 2004) may be differently affected by the predictors in each of the studies presented. However, this limitation highlights opportunities for additional research within maths education, and the findings provide some suggestion of potential research areas for further examination when comparing attainment between typically-developing children and children with dyscalculia or other special educational needs.

Based on the key findings and the limitations of the studies (which are discussed in greater depth within the individual chapters), there are further opportunities for research to follow on from the work presented in this thesis. The role of parents within maths education is one of the key areas for future research stemming from the findings of Chapters 3 and 4. We now know that higher-educated parents have considerably higher-achieving children, even when factors such as child IQ, SES, parental mental health, and involvement in school are adjusted for. And so it remains unknown exactly *how* the educational qualifications of parents benefit their children which is one recommendation for future research. Based on the findings presented and the wider literature, suggestions for research in this area are to focus on investigating the ways in which higher-educated parents differ to lower-educated parents particularly during parent-child interactions involving maths and numeracy activities, and also in the intergenerational transmission of maths anxiety and maths-related affect.

Another key finding that warrants further investigation is the association between maths attitudes and attainment during primary and secondary education. This is a

potential area for further research because the results showed a substantial effect size in primary and secondary education and could potentially be very useful in improving maths attainment. Further research should focus on establishing causality to assess the extent to which maths attitudes affect attainment. Research examining maths attitudes and affect in secondary education is particularly sparse and further studies would be useful when designing maths education strategies.

One final recommendation for future work is to investigate predictors of maths attainment in more diverse samples using more time-appropriate measures. As discussed above, the studies focused on typically developing children, and had participants that were more likely to be white, of higher SES, and with greater educational attainment. The data from ALSPAC are now somewhat outdated, and because of various changes in adolescents' social and educational environments that have occurred since the data was originally collected, it would be particularly useful to utilise more recent data in future studies to adjust for these differences. A lack of time-appropriate measures (i.e. those measured across the transition) was also evident in the ALSPAC and TEDS datasets which made it difficult to draw definitive conclusions regarding the effect of the transition event on attainment which should be taken into consideration when planning future studies within this area.

Conclusion

This thesis investigated the effects associated with the transition from primary to secondary education, particularly focusing on children's maths attainment trajectories. The empirical chapters centred around cognitive, emotional, environmental, and social factors that might influence maths attainment during this transitional period. This work

contributes to existing literature by showing that of the aforementioned areas, internalising symptoms, working memory, maths attitudes, school affect, student-teacher relationships, parental education qualifications, parental school involvement, and parent-child relationships are all *substantially* associated with maths attainment trajectories in adolescence. Additionally, emotional symptoms and low maths attainment across the transition were shown to be associated with increased maths anxiety in adulthood. The identification of these predictors can be used to better inform transition strategies from primary to secondary education to help improve educational outcomes that we know are negatively affected during the transition. This thesis additionally helps to address the reported ‘maths crisis’ in the UK (Carey et al., 2019) by identifying key areas for potential interventions for improving low maths attainment. It is hoped that by further understanding the factors associated with maths attainment and the primary-secondary education transition, we can facilitate children in making well-adapted transitions to secondary education, and ensure all children succeed in maths.

References

- Abu-Hilal, M. M. (2000). A structural model for predicting mathematics achievement: Its relation with anxiety and self-concept in mathematics. *Psychological Reports*, 86(3), 835–847. <https://doi.org/10.2466/pr0.2000.86.3.835>
- Abulizi, X., Pryor, L., Michel, G., Melchior, M., Van Der Waerden, J., & Group, E. M. C. S. (2017). Temperament in infancy and behavioral and emotional problems at age 5.5: The eden mother-child cohort. *PLoS One*, 12(2), e0171971. <https://doi.org/10.1371/journal.pone.0171971>
- Acock, A. C. (2005). Working with missing values. *Journal of Marriage and Family*, 67(4), 1012–1028. <https://doi.org/10.1111/j.1741-3737.2005.00191.x>
- Adams, J. W., Snowling, M. J., Hennessy, S. M., & Kind, P. (1999). Problems of behaviour, reading and arithmetic: Assessments of comorbidity using the strengths and difficulties questionnaire. *British Journal of Educational Psychology*, 69(4), 571–585. <https://doi.org/10.1348/000709999157905>
- Adrian, M., Miller, A. B., McCauley, E., & Vander Stoep, A. (2016). Suicidal ideation in early to middle adolescence: Sex-specific trajectories and predictors. *Journal of Child Psychology and Psychiatry*, 57(5), 645–653. <https://doi.org/10.1111/jcpp.12484>
- Akos, P., & Galassi, J. P. (2004). Middle and high school transitions as viewed by students, parents, and teachers. *Professional School Counseling*, 212–221.

- Akos, P., Rose, R. A., & Orthner, D. (2015). Sociodemographic moderators of middle school transition effects on academic achievement. *The Journal of Early Adolescence*, 35(2), 170–198. <https://doi.org/10.1177/0272431614529367>
- Alloway, T. P., & Alloway, R. G. (2010). Investigating the predictive roles of working memory and iq in academic attainment. *Journal of Experimental Child Psychology*, 106(1), 20–29. <https://doi.org/10.1016/j.jecp.2009.11.003>
- Alspaugh, J. W. (1998). Achievement loss associated with the transition to middle school and high school. *The Journal of Educational Research*, 92(1), 20–25. <https://doi.org/10.1080/00220679809597572>
- Alspaugh, J. W., & Harting, R. D. (1995). Transition effects of school grade-level organization on student achievement. *Journal of Research & Development in Education*.
- Amato, P. R., & Fowler, F. (2002). Parenting practices, child adjustment, and family diversity. *Journal of Marriage and Family*, 64(3), 703–716. <https://doi.org/10.1111/j.1741-3737.2002.00703.x>
- Anderman, E. M. (1998). The middle school experience: Effects on the math and science achievement of adolescents with ld. *Journal of Learning Disabilities*, 31(2), 128–138. <https://doi.org/10.1177/002221949803100203>
- Anderman, E. M., & Midgley, C. (1997). Changes in achievement goal orientations, perceived academic competence, and grades across the transition to middle-level schools. *Contemporary Educational Psychology*, 22(3), 269–298. <https://doi.org/10.1006/ceps.1996.0926>

- Anderson, L. W., Jacobs, J., Schramm, S., & Splittgerber, F. (2000). School transitions: Beginning of the end or a new beginning? *International Journal of Educational Research*, 33(4), 325–339. [https://doi.org/10.1016/S0883-0355\(00\)00020-3](https://doi.org/10.1016/S0883-0355(00)00020-3)
- Andersson, U. (2007). The contribution of working memory to children's mathematical word problem solving. *Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition*, 21(9), 1201–1216. <https://doi.org/10.1002/acp.1317>
- APA. (2017a). Anxiety. Retrieved from <http://www.apa.org/topics/anxiety/index.aspx>
- APA. (2017b). Depression. Retrieved from <http://www.apa.org/topics/depression/index.aspx>
- APA. (2017c). Glossary of psychological terms. Retrieved from <https://dictionary.apa.org/>
- Arens, A. K., Yeung, A. S., Craven, R. G., Watermann, R., & Hasselhorn, M. (2013a). Does the timing of transition matter? Comparison of german students' self-perceptions before and after transition to secondary school. *International Journal of Educational Research*, 57, 1–11. <https://doi.org/10.1016/j.ijer.2012.11.001>
- Arens, A. K., Yeung, A. S., Nagengast, B., & Hasselhorn, M. (2013b). Relationship between self-esteem and academic self-concept for german elementary and secondary school students. *Educational Psychology*, 33(4), 443–464. <https://doi.org/10.1080/01443410.2013.772772>

- Arowosafe, D. S., & Irvin, J. L. (1992). Transition to a middle level school: What kids say. *Middle School Journal*, 24(2), 15–19.
<https://doi.org/10.1080/00940771.1992.11495162>
- Ashcraft, M. H. (2002). Math anxiety: Personal, educational, and cognitive consequences. *Current Directions in Psychological Science*, 11(5), 181–185.
<https://doi.org/10.1111/1467-8721.00196>
- Ashcraft, M. H., & Kirk, E. P. (2001). The relationships among working memory, math anxiety, and performance. *Journal of Experimental Psychology: General*, 130(2), 224–237. <https://doi.org/10.1037//0096-3445.130.2.224>
- Ashcraft, M. H., & Krause, J. A. (2007). Working memory, math performance, and math anxiety. *Psychonomic Bulletin & Review*, 14(2), 243–248.
<https://doi.org/10.3758/BF03194059>
- Ashcraft, M. H., & Moore, A. M. (2009). Mathematics anxiety and the affective drop in performance. *Journal of Psychoeducational Assessment*, 27(3), 197–205.
<https://doi.org/10.1177/0734282908330580>
- Ashcraft, M. H., & Ridley, K. S. (2005). Math anxiety and its cognitive consequences: A tutorial review. In J. I. D. Campbell (Ed.), *Handbook of mathematical cognition* (pp. 315–327). New York, NY, US: Psychology Press.
- Axelson, D. A., & Birmaher, B. (2001). Relation between anxiety and depressive disorders in childhood and adolescence. *Depression and Anxiety*, 14(2), 67–78.
<https://doi.org/10.1002/da.1048>

- Bachman, J. G., & O'Malley, P. M. (1977). Self-esteem in young men: A longitudinal analysis of the impact of educational and occupational attainment. *Journal of Personality and Social Psychology*, 35(6), 365–380.
<https://doi.org/10.1037/0022-3514.35.6.365>
- Baddeley, A. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences*, 4(11), 417–423. [https://doi.org/10.1016/s1364-6613\(00\)01538-2](https://doi.org/10.1016/s1364-6613(00)01538-2)
- Bailey, S., & Baines, E. (2012). The impact of risk and resiliency factors on the adjustment of children after the transition from primary to secondary school. *Educational and Child Psychology*, 29(1), 47–63.
- Barger, M. M., Kim, E. M., Kuncel, N. R., & Pomerantz, E. M. (2019). The relation between parents' involvement in children's schooling and children's adjustment: A meta-analysis. *Psychological Bulletin*, 145(9), 855–890.
<https://doi.org/10.1037/bul0000201>
- Barile, J. P., Donohue, D. K., Anthony, E. R., Baker, A. M., Weaver, S. R., & Henrich, C. C. (2012). Teacher–student relationship climate and school outcomes: Implications for educational policy initiatives. *Journal of Youth and Adolescence*, 41(3), 256–267. <https://doi.org/10.1007/s10964-011-9652-8>
- Barth, J. M., Todd, B., McCallum, D., Goldston, D., Guadagno, R., Roskos, B., & Burkhalter, C. (2011). Effects of engaging classroom strategies and teacher support on student outcomes over school transitions. *ASCE Annual Conference*

and Exposition, Conference Proceedings (Vancouver International Conference Centre, June 2011).

Battistich, V., Schaps, E., & Wilson, N. (2004). Effects of an elementary school intervention on students' "connectedness" to school and social adjustment during middle school. *Journal of Primary Prevention*, 24(3), 243–262.

<https://doi.org/10.1023/B:JOPP.0000018048.38517.cd>

Baudoin, N., & Galand, B. (2017). Effects of classroom goal structures on student emotions at school. *International Journal of Educational Research*, 86, 13–22.

<https://doi.org/10.1016/j.ijer.2017.08.010>

Beilock, S. L., Gunderson, E. A., Ramirez, G., & Levine, S. C. (2010). Female teachers' math anxiety affects girls' math achievement. *Proceedings of the National Academy of Sciences*, 107(5), 1860–1863.

<https://doi.org/10.1073/pnas.0910967107>

Beilock, S. L., & Maloney, E. A. (2015). Math anxiety: A factor in math achievement not to be ignored. *Policy Insights from the Behavioral and Brain Sciences*, 2(1), 4–12. <https://doi.org/10.1177/2372732215601438>

Benner, A. D., & Graham, S. (2009). The transition to high school as a developmental process among multiethnic urban youth. *Child Development*, 80(2), 356–376.

<https://doi.org/10.1111/j.1467-8624.2009.01265.x>.

Bennett, A. (2017). *Early numerical experiences* (PhD thesis). Loughborough University. Retrieved from <https://hdl.handle.net/2134/32451>

- Berndt, T. J., & Mekos, D. (1995). Adolescents' perceptions of the stressful and desirable aspects of the transition to junior high school. *Journal of Research on Adolescence*, 5(1), 123–142. https://doi.org/10.1207/s15327795jra0501_6
- Betz, N. E. (1978). Prevalence, distribution, and correlates of math anxiety in college students. *Journal of Counseling Psychology*, 25(5), 441–448. <https://doi.org/10.1037/0022-0167.25.5.441>
- Birtchnell, J., Evans, C., & Kennard, J. (1988). The total score of the crown-crisp experiential index: A useful and valid measure of psychoneurotic pathology. *British Journal of Medical Psychology*, 61(3), 255–266. <https://doi.org/10.1111/j.2044-8341.1988.tb02787.x>
- Blakemore, J. E. O., & Centers, R. E. (2005). Characteristics of boys' and girls' toys. *Sex Roles*, 53(9-10), 619–633. <https://doi.org/10.1007/s11199-005-7729-0>
- Blevins-Knabe, B., & Musun-Miller, L. (1996). Number use at home by children and their parents and its relationship to early mathematical performance. *Early Development and Parenting: An International Journal of Research and Practice*, 5(1), 35–45. [https://doi.org/10.1002/\(SICI\)1099-0917\(199603\)5:1<35::AID-EDP113>3.0.CO2-0](https://doi.org/10.1002/(SICI)1099-0917(199603)5:1<35::AID-EDP113>3.0.CO2-0)
- Booth-LaForce, C., Oh, W., Kennedy, A. E., Rubin, K. H., Rose-Krasnor, L., & Laursen, B. (2012). Parent and peer links to trajectories of anxious withdrawal from grades 5 to 8. *Journal of Clinical Child & Adolescent Psychology*, 41(2), 138–149. <https://doi.org/10.1080/15374416.2012.651995>

- Boyd, A., Golding, J., Macleod, J., Lawlor, D. A., Fraser, A., Henderson, J., ... Smith, G. D. (2013). Cohort profile: The 'Children of the 90s'-The index offspring of the avon longitudinal study of parents and children. *International Journal of Epidemiology*, 42(1), 111–127. <https://doi.org/10.1093/ije/dys064>
- BPS. (2017). Briefing paper: Children and young people's mental health (cypmh): Schools and colleges. Retrieved from <https://www.bps.org.uk/sites/bps.org.uk/files/Policy%20-%20Files/Briefing%20Paper%20-%20CYPMH%20Schools%20and%20Colleges.pdf>
- Bradley, R. H., & Corwyn, R. F. (2002). Socioeconomic status and child development. *Annual Review of Psychology*, 53(1), 371–399. <https://doi.org/10.1146/annurev.psych.53.100901.135233>
- Brooks-Gunn, J., Klebanov, P. K., & Duncan, G. J. (1996). Ethnic differences in children's intelligence test scores: Role of economic deprivation, home environment, and maternal characteristics. *Child Development*, 67(2), 396–408. <https://doi.org/10.2307/1131822>
- Bru, E., Stornes, T., Munthe, E., & Thuen, E. (2010). Students' perceptions of teacher support across the transition from primary to secondary school. *Scandinavian Journal of Educational Research*, 54(6), 519–533. <https://doi.org/10.1080/00313831.2010.522842>
- Bryce, C. I., Bradley, R. H., Abry, T., Swanson, J., & Thompson, M. S. (2019). Parents' and teachers' academic influences, behavioral engagement, and first-and fifth-

grade achievement. *School Psychology*, 34(5), 492–502.

<https://doi.org/10.1037/spq0000297>

Bull, R., Espy, K. A., & Wiebe, S. A. (2008). Short-term memory, working memory, and executive functioning in preschoolers: Longitudinal predictors of mathematical achievement at age 7 years. *Developmental Neuropsychology*, 33(3), 205–228. <https://doi.org/10.1080/87565640801982312>

Bull, R., & Scerif, G. (2001). Executive functioning as a predictor of children's mathematics ability: Inhibition, switching, and working memory. *Developmental Neuropsychology*, 19(3), 273–293.
https://doi.org/10.1207/S15326942DN1903_3

Buss, A. H., & Plomin, R. (1986). The EAS approach to temperament. In R. Plomin & J. Dunn (Eds.), *The Study of Temperament: Changes, Continuities and Challenges*. Hillsdale, NJ: Lawrence Erlbaum.

Cai, J. (2003). Investigating parental roles in students' learning of mathematics from a cross-national perspective. *Mathematics Education Research Journal*, 15(2), 87–106. <https://doi.org/10.1007/BF03217372>

Cantin, S., & Boivin, M. (2004). Change and stability in children's social network and self-perceptions during transition from elementary to junior high school. *International Journal of Behavioral Development*, 28(6), 561–570.
<https://doi.org/10.1080/01650250444000289>

Carey, E., Devine, A., Hill, F., Dowker, A., McLellan, R., & Szucs, D. (2019). *Understanding mathematics anxiety: Investigating the experiences of uk primary*

and secondary school students. University of Cambridge: Centre for Neuroscience in Education. <https://doi.org/10.17863/CAM.37744>

Carey, E., Devine, A., Hill, F., & Szűcs, D. (2017). Differentiating anxiety forms and their role in academic performance from primary to secondary school. *PLoS One*, 12(3), e0174418. <https://doi.org/10.1371/journal.pone.0174418>

Carey, E., Hill, F., Devine, A., & Szűcs, D. (2016). The chicken or the egg? The direction of the relationship between mathematics anxiety and mathematics performance. *Frontiers in Psychology*, 6, 1987. <https://doi.org/10.3389/fpsyg.2015.01987>

Cargnelutti, E., Tomasetto, C., & Passolunghi, M. C. (2017). How is anxiety related to math performance in young students? A longitudinal study of grade 2 to grade 3 children. *Cognition and Emotion*, 31(4), 755–764. <https://doi.org/10.1080/02699931.2016.1147421>

Cartwright-Hatton, S., McNicol, K., & Doubleday, E. (2006). Anxiety in a neglected population: Prevalence of anxiety disorders in pre-adolescent children. *Clinical Psychology Review*, 26(7), 817–833. <https://doi.org/10.1016/j.cpr.2005.12.002>

Case, R., Kurland, D. M., & Goldberg, J. (1982). Operational efficiency and the growth of short-term memory span. *Journal of Experimental Child Psychology*, 33(3), 386–404. [https://doi.org/10.1016/0022-0965\(82\)90054-6](https://doi.org/10.1016/0022-0965(82)90054-6)

Chaman, M. J., Beswick, K., & Callingham, R. (2014). Factors influencing mathematics achievement among secondary school students. In *The future of educational*

research. *Bold visions in educational research* (pp. 227–238). Rotterdam: SensePublishers. https://doi.org/10.1007/978-94-6209-512-0_19

Chang, H., & Beilock, S. L. (2016). The math anxiety-math performance link and its relation to individual and environmental factors: A review of current behavioral and psychophysiological research. *Current Opinion in Behavioral Sciences*, 10, 33–38. <https://doi.org/10.1016/j.cobeha.2016.04.011>

Chen, L., Bae, S. R., Battista, C., Qin, S., Chen, T., Evans, T. M., & Menon, V. (2018). Positive attitude toward math supports early academic success: Behavioral evidence and neurocognitive mechanisms. *Psychological Science*, 29(3), 390–402. <https://doi.org/10.1177/0956797617735528>

Children’s Commissioner. (2018). *Life in “likes”: Children’s commissioner report into social media use among 8-12 year olds*. London: Office of the Children’s Commissioner.

Chinn, S. (2009). Mathematics anxiety in secondary students in england. *Dyslexia*, 15(1), 61–68. <https://doi.org/10.1002/dys.381>

Christensen, K., Petersen, I., Skytthe, A., Herskind, A. M., McGue, M., & Bingley, P. (2006). Comparison of academic performance of twins and singletons in adolescence: Follow-up study. *Bmj*, 333(7578), 1095. <https://doi.org/10.1136/bmj.38959.650903.7C>

Chung, H., Elias, M., & Schneider, K. (1998). Patterns of individual adjustment changes during middle school transition. *Journal of School Psychology*, 36(1), 83–101. [https://doi.org/10.1016/S0022-4405\(97\)00051-4](https://doi.org/10.1016/S0022-4405(97)00051-4)

- Cillessen, A. H., & Mayeux, L. (2007). Expectations and perceptions at school transitions: The role of peer status and aggression. *Journal of School Psychology, 45*(5), 567–586. <https://doi.org/10.1016/j.jsp.2007.05.004>
- Claessens, A., & Engel, M. (2013). How important is where you start? Early mathematics knowledge and later school success. *Teachers College Record, 115*(6), 1–29.
- Coelho, V. A., Marchante, M., & Jimerson, S. R. (2017). Promoting a positive middle school transition: A randomized-controlled treatment study examining self-concept and self-esteem. *Journal of Youth and Adolescence, 46*(3), 558–569. <https://doi.org/10.1007/s10964-016-0510-6>
- Coelho, V. A., & Romão, A. M. (2016). Stress in portuguese middle school transition: A multilevel analysis. *The Spanish Journal of Psychology, 19*, 1–8. <https://doi.org/10.1017/sjp.2016.61>
- Coelho, V. A., Romão, A. M., Brás, P., Bear, G., & Prioste, A. (2020). Trajectories of students' school climate dimensions throughout middle school transition: A longitudinal study. *Child Indicators Research, 13*(1), 175–192. <https://doi.org/10.1007/s12187-019-09674-y>
- Coffey, A. (2013). Relationships: The key to successful transition from primary to secondary school? *Improving Schools, 16*(3), 261–271. <https://doi.org/10.1177/1365480213505181>

- Cohen, J., McCabe, L., Michelli, N. M., & Pickeral, T. (2009). School climate: Research, policy, practice, and teacher education. *Teachers College Record*, 111(1), 180–213.
- Cohen, S., & Wills, T. A. (1985). Stress, social support, and the buffering hypothesis. *Psychological Bulletin*, 98(2), 310–357. <https://doi.org/10.1037/0033-2909.98.2.310>
- Collins, T. N., & Parson, K. A. (2010). School climate and student outcomes. *Journal of Cross-Disciplinary Perspectives in Education*, 3(1), 34–39.
- Colmar, S., & Double, K. (2017). Working memory interventions with children: Classrooms or computers? *Journal of Psychologists and Counsellors in Schools*, 27(2), 264–277. <https://doi.org/10.1017/jgc.2017.11>
- Costa, P. T., & McCrae, R. R. (1992). *Revised neo personality inventory and neo five-factor inventory professional manual*. Odessa: FL: Psychological Assessment Resources.
- Costello, E. J., Copeland, W., & Angold, A. (2011). Trends in psychopathology across the adolescent years: What changes when children become adolescents, and when adolescents become adults? *Journal of Child Psychology and Psychiatry*, 52(10), 1015–1025. <https://doi.org/10.1111/j.1469-7610.2011.02446.x>
- Cox, J. L., Chapman, G., Murray, D., & Jones, P. (1996). Validation of the edinburgh postnatal depression scale (epds) in non-postnatal women. *Journal of Affective Disorders*, 39(3), 185–189. [https://doi.org/10.1016/0165-0327\(96\)00008-0](https://doi.org/10.1016/0165-0327(96)00008-0)

- Cox, J. L., Holden, J., & Sagovsky, R. (1987). Detection of postnatal depression. Development of the 10-item edinburgh postnatal depression scale. *The British Journal of Psychiatry*, 159(5), 782–786. <https://doi.org/10.1192/bjp.150.6.782>
- Cragg, L., & Gilmore, C. (2014). Skills underlying mathematics: The role of executive function in the development of mathematics proficiency. *Trends in Neuroscience and Education*, 3(2), 63–68. <https://doi.org/10.1016/j.tine.2013.12.001>
- Creswell, C., Cooper, P., & Murray, L. (2010). Intergenerational transmission of anxious information processing biases. In J. A. Hadwin & A. P. Field (Eds.), *Information processing biases and anxiety* (pp. 279–295). Chichester: Wiley-Blackwell. <https://doi.org/10.1002/9780470661468.ch12>
- Crick, N. R., & Grotpeter, J. K. (1995). Relational aggression, gender, and social-psychological adjustment. *Child Development*, 66(3), 710–722. <https://doi.org/10.2307/1131945>
- Crockett, L. J., Petersen, A. C., Graber, J. A., Schulenberg, J. E., & Ebata, A. (1989). School transitions and adjustment during early adolescence. *The Journal of Early Adolescence*, 9(3), 181–210. <https://doi.org/10.1177/0272431689093002>
- Crown, S., & Crisp, A. H. (1979). *Manual of the crown-crisp experiential index*. London: Hodder; Stoughton.
- Day, J. C., & Newburger, E. C. (2002). *The big payoff: Educational attainment and synthetic estimates of work-life earnings. Special studies. Current population reports*. Washington, DC: U.S. Census Bureau.

- Deary, I. J., Strand, S., Smith, P., & Fernandes, C. (2007). Intelligence and educational achievement. *Intelligence*, 35(1), 13–21.
<https://doi.org/10.1016/j.intell.2006.02.001>
- Deieso, D., & Fraser, B. J. (2019). Learning environment, attitudes and anxiety across the transition from primary to secondary school mathematics. *Learning Environments Research*, 133–152. <https://doi.org/10.1007/s10984-018-9261-5>
- Demaray, M. K., & Malecki, C. K. (2002). The relationship between perceived social support and maladjustment for students at risk. *Psychology in the Schools*, 39(3), 305–316. <https://doi.org/10.1002/pits.10018>
- Department for Children, Schools and Families. (2008). *The impact of parental involvement on children's education*. Nottingham: DCSF.
- Desforges, C., & Abouchaar, A. (2003). *The impact of parental involvement, parental support and family education on pupil achievement and adjustment: A literature review* (Vol. 433). London: DfES.
- DeStefano, D., & LeFevre, J.-A. (2004). The role of working memory in mental arithmetic. *European Journal of Cognitive Psychology*, 16(3), 353–386.
<https://doi.org/10.1080/09541440244000328>
- Devine, A., Fawcett, K., Szűcs, D., & Dowker, A. (2012). Gender differences in mathematics anxiety and the relation to mathematics performance while controlling for test anxiety. *Behavioral and Brain Functions*, 8(1), 33.
<https://doi.org/10.1186/1744-9081-8-33>

- Devine, A., Hill, F., Carey, E., & Szűcs, D. (2018). Cognitive and emotional math problems largely dissociate: Prevalence of developmental dyscalculia and mathematics anxiety. *Journal of Educational Psychology*, 110(3), 431. <https://doi.org/10.1037/edu0000222>
- Diener, E., & Diener, M. (1995). Cross-cultural correlates of life satisfaction and self-esteem. *Journal of Personality and Social Psychology*, 68(4), 653–663. <https://doi.org/10.1037/0022-3514.68.4.653>
- Ditch the label. (2019). The annual bullying survey 2019. Retrieved from <https://www.ditchthelabel.org/research-papers/the-annual-bullying-survey-2019/>
- Dobbs, J., Doctoroff, G. L., Fisher, P. H., & Arnold, D. H. (2006). The association between preschool children's socio-emotional functioning and their mathematical skills. *Journal of Applied Developmental Psychology*, 27(2), 97–108. <https://doi.org/10.1016/j.appdev.2005.12.008>
- Dotterer, A. M., McHale, S. M., & Crouter, A. C. (2009). The development and correlates of academic interests from childhood through adolescence. *Journal of Educational Psychology*, 101(2), 509–519. <https://doi.org/10.1037/a0013987>
- Dowker, A., Bennett, K., & Smith, L. (2012). Attitudes to mathematics in primary school children. *Child Development Research*, 2012, 1–8. <https://doi.org/10.1155/2012/124939>
- Dowker, A., Cheriton, O., Horton, R., & Mark, W. (2019). Relationships between attitudes and performance in young children's mathematics. *Educational Studies in Mathematics*, 100(3), 211–230. <https://doi.org/10.1007/s10649-019-9880-5>

- Dowker, A., Sarkar, A., & Looi, C. Y. (2016). Mathematics anxiety: What have we learned in 60 years? *Frontiers in Psychology*, 7, 508.
<https://doi.org/10.3389/fpsyg.2016.00508>
- Dubow, E. F., Boxer, P., & Huesmann, L. R. (2009). Long-term effects of parents' education on children's educational and occupational success: Mediation by family interactions, child aggression, and teenage aspirations. *Merrill-Palmer Quarterly (Wayne State University. Press)*, 55(3), 224–249.
<https://doi.org/10.1353/mpq.0.0030>
- Duchesne, S., Ratelle, C. F., Poitras, S.-C., & Drouin, E. (2009). Early adolescent attachment to parents, emotional problems, and teacher-academic worries about the middle school transition. *The Journal of Early Adolescence*, 29(5), 743–766.
<https://doi.org/10.1177/0272431608325502>
- Duchesne, S., Ratelle, C. F., & Roy, A. (2012). Worries about middle school transition and subsequent adjustment: The moderating role of classroom goal structure. *The Journal of Early Adolescence*, 32(5), 681–710.
<https://doi.org/10.1177/0272431611419506>
- Duineveld, J. J., Parker, P. D., Ryan, R. M., Ciarrochi, J., & Salmela-Aro, K. (2017). The link between perceived maternal and paternal autonomy support and adolescent well-being across three major educational transitions. *Developmental Psychology*, 53(10), 1978. <https://doi.org/10.1037/dev0000364>

- Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., ... others. (2007). School readiness and later achievement. *Developmental Psychology*, 43(6), 1428. <https://doi.org/10.1037/0012-1649.43.6.1428>
- Eccles, J. S. (2005). Influences of parents' education on their children's educational attainments: The role of parent and child perceptions. *London Review of Education*, 3(3), 191–204. <https://doi.org/10.1080/14748460500372309>
- Eccles, J. S., & Midgley, C. (1989). Stage-environment fit: Developmentally appropriate classrooms for young adolescents. In R. Ames & A. C (Eds.), *Research on motivation in education: Vol. 3. Goals and cognitions* (pp. 13–44). New York, NY: Academic Press.
- Eccles, J. S., Midgley, C., & Alder, T. (1984). Grade-related changes in the school environment: Effects on achievement motivation. In J. H. Nicholls (Ed.), *The development of achievement motivation* (pp. 283–331). Greenwich, CT: JAI.
- Eccles, J. S., Midgley, C., Wigfield, A., Buchanan, C. M., Reuman, D., Flanagan, C., & Mac Iver, D. (1993). Development during adolescence: The impact of stage-environment fit on young adolescents' experiences in schools and in families. *American Psychologist*, 48(2), 90–101. <https://doi.org/10.1037/0003-066X.48.2.90>
- Eccles, J. S., & Roeser, R. W. (2009). Schools, academic motivation, and stage-environment fit. In L. R. M & S. L. D (Eds.), *Handbook of adolescent psychology* (pp. 404–434). Hoboken: Wiley.

- Egger, H. L., & Angold, A. (2006). Common emotional and behavioral disorders in preschool children: Presentation, nosology, and epidemiology. *Journal of Child Psychology and Psychiatry*, 47(3-4), 313–337. <https://doi.org/10.1111/j.1469-7610.2006.01618.x>
- Eley, T. C., McAdams, T. A., Rijdsdijk, F. V., Lichtenstein, P., Narusyte, J., Reiss, D., ... Neiderhiser, J. M. (2015). The intergenerational transmission of anxiety: A children-of-twins study. *American Journal of Psychiatry*, 172(7), 630–637. <https://doi.org/10.1176/appi.ajp.2015.14070818>
- Else-Quest, N. M., Mineo, C. C., & Higgins, A. (2013). Math and science attitudes and achievement at the intersection of gender and ethnicity. *Psychology of Women Quarterly*, 37(3), 293–309. <https://doi.org/10.1177/0361684313480694>
- Enders, C. K. (2017). Multiple imputation as a flexible tool for missing data handling in clinical research. *Behaviour Research and Therapy*, 98, 4–18. <https://doi.org/10.1016/j.brat.2016.11.008>
- Enders, C. K., & Bandalos, D. L. (2001). The relative performance of full information maximum likelihood estimation for missing data in structural equation models. *Structural Equation Modeling*, 8(3), 430–457. https://doi.org/10.1207/S15328007SEM0803_5
- Espy, K. A., McDiarmid, M. M., Cwik, M. F., Stalets, M. M., Hamby, A., & Senn, T. E. (2004). The contribution of executive functions to emergent mathematic skills in preschool children. *Developmental Neuropsychology*, 26(1), 465–486. https://doi.org/10.1207/s15326942dn2601_6

- Evangelou, M., Taggart, B., Sylva, K., Melhuish, E., Sammons, P., & Siraj-Blatchford, I. (2008). *What makes a successful transition from primary to secondary school?* London, UK: Department for Children, Schools; Families.
- Evans, D., Borriello, G. A., & Field, A. P. (2018). A review of the academic and psychological impact of the transition to secondary education. *Frontiers in Psychology*, 9, 1482. <https://doi.org/10.3389/fpsyg.2018.01482>
- Evans, D., & Field, A. P. (2020). Predictors of mathematical attainment trajectories across the primary-to-secondary education transition: Parental factors and the home environment. *Royal Society Open Science*, 7(7), 200422. <https://doi.org/10.1098/rsos.200422>
- Evans, D., Gaysina, D., & Field, A. P. (2020). Internalizing symptoms and working memory as predictors of mathematical attainment trajectories across the primary–secondary education transition. *Royal Society Open Science*, 7(5), 191433. <https://doi.org/10.1098/rsos.191433>
- Every Child a Chance Trust. (2009). The long-term costs of numeracy difficulties. Retrieved from <https://www.shinetrust.org.uk/wp-content/uploads/ECC-Long-Term-Costs-Numeracy.pdf>
- Eysenck, M. W., & Calvo, M. G. (1992). Anxiety and performance: The processing efficiency theory. *Cognition & Emotion*, 6(6), 409–434. <https://doi.org/10.1080/02699939208409696>

- Eysenck, M. W., & Derakshan, N. (2011). New perspectives in attentional control theory. *Personality and Individual Differences*, 50(7), 955–960.
<https://doi.org/10.1016/j.paid.2010.08.019>
- Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion*, 7(2), 336–353.
<https://doi.org/10.1037/1528-3542.7.2.336>
- Fan, X., & Chen, M. (2001). Parental involvement and students' academic achievement: A meta-analysis. *Educational Psychology Review*, 13(1), 1–22.
<https://doi.org/10.1023/A:1009048817385>
- Faust, M. W. (1996). Mathematics anxiety effects in simple and complex addition. *Mathematical Cognition*, 2(1), 25–62. <https://doi.org/10.1080/135467996387534>
- Federici, R. A., Skaalvik, E. M., & Tangen, T. N. (2015). Students' perceptions of the goal structure in mathematics classrooms: Relations with goal orientations, mathematics anxiety, and help-seeking behavior. *International Education Studies*, 8(3), 146–158. <https://doi.org/10.5539/ies.v8n3p146>
- Felner, R. D., Primavera, J., & Cauce, A. M. (1981). The impact of school transitions: A focus for preventive efforts. *American Journal of Community Psychology*, 9(4), 449–459. <https://doi.org/10.1007/BF00918175>
- Fenzel, L. M. (2000). Prospective study of changes in global self-worth and strain during the transition to middle school. *The Journal of Early Adolescence*, 20(1), 93–116. <https://doi.org/10.1177/0272431600020001005>

- Fenzel, L. M., & Blyth, D. A. (1986). Individual adjustment to school transitions: An exploration of the role of supportive peer relations. *The Journal of Early Adolescence*, 6(4), 315–329. <https://doi.org/10.1177/0272431686064003>
- Field, A. P. (2010). Teaching Statistics. In D. Upton & A. Trapp (Eds.), *Teaching Psychology in Higher Education* (pp. 134–163). Chichester, UK: Wiley-Blackwell.
- Field, A. P. (2014). *Skills in Mathematics and Statistics in Psychology and tackling transition*. Higher Education Academy.
- Field, A. P., Evans, D., Bloniewski, T., & Kovas, Y. (2019). Predicting maths anxiety from mathematical achievement across the transition from primary- to secondary-education. *Royal Society Open Science*, 6, 191459. <https://doi.org/10.1098/rsos.191459>
- Field, A. P., & Purkis, H. M. (2011). The role of learning in the aetiology of child and adolescent fear and anxiety. In W. K. Silverman & A. P. Field (Eds.), *Anxiety disorders in children and adolescents: Research, assessment and intervention* (pp. 227–256). Cambridge: Cambridge University Press.
- Finn, J. D., Fish, R. M., & Scott, L. A. (2008). Educational sequelae of high school misbehavior. *The Journal of Educational Research*, 101(5), 259–274. <https://doi.org/10.3200/JOER.101.5.259-274>
- Fiscella, K., & Kitzman, H. (2009). Disparities in academic achievement and health: The intersection of child education and health policy. *Pediatrics*, 123(3), 1073–1080. <https://doi.org/10.1542/peds.2008-0533>

- Fox, J. (2019). *Polychoric and polyserial correlations*. Retrieved from <https://cran.r-project.org/web/packages/polycor/polycor.pdf>
- Fraser, A., Macdonald-Wallis, C., Tilling, K., Boyd, A., Golding, J., Smith, G. D., ... Lawlor, D. A. (2013). Cohort profile: The avon longitudinal study of parents and children: ALSPAC mothers cohort. *International Journal of Epidemiology*, 42(1), 97–110. <https://doi.org/10.1093/ije/dys066>
- Frenzel, A. C., Goetz, T., Pekrun, R., & Watt, H. M. (2010). Development of mathematics interest in adolescence: Influences of gender, family, and school context. *Journal of Research on Adolescence*, 20(2), 507–537. <https://doi.org/10.1111/j.1532-7795.2010.00645.x>
- Freudenberg, N., & Ruglis, J. (2007). Peer reviewed: Reframing school dropout as a public health issue. *Preventing Chronic Disease*, 4(4), A107.
- Fröjd, S. A., Nissinen, E. S., Pelkonen, M. U. I., Marttunen, M. J., Koivisto, A.-M., & Kaltiala-Heino, R. (2008). Depression and school performance in middle adolescent boys and girls. *Journal of Adolescence*, 31(4), 485–498. <https://doi.org/10.1016/j.adolescence.2007.08.006>
- Galton, M., Gray, J., & Ruddock, J. (1999). *The impact of school transitions and transfers on pupil progress and attainment*. London: DfEE.
- Gathercole, S. E., & Pickering, S. J. (2000). Working memory deficits in children with low achievements in the national curriculum at 7 years of age. *British Journal of Educational Psychology*, 70(2), 177–194. <https://doi.org/10.1348/000709900158047>

- Gathercole, S. E., Pickering, S. J., Knight, C., & Stegmann, Z. (2004). Working memory skills and educational attainment: Evidence from national curriculum assessments at 7 and 14 years of age. *Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition*, 18(1), 1–16. <https://doi.org/10.1002/acp.934>
- Geary, D. C. (1993). Mathematical disabilities: Cognitive, neuropsychological, and genetic components. *Psychological Bulletin*, 114(2), 345–362. <https://doi.org/10.1037/0033-2909.114.2.345>
- Geary, D. C. (2000). From infancy to adulthood: The development of numerical abilities. *European Child & Adolescent Psychiatry*, 9(2), 11–16. <https://doi.org/10.1007/s007870070004>
- Geary, D. C. (2011a). Cognitive predictors of achievement growth in mathematics: A 5-year longitudinal study. *Developmental Psychology*, 47(6), 1539–1552. <https://doi.org/10.1037/a0025510>
- Geary, D. C. (2011b). Consequences, characteristics, and causes of mathematical learning disabilities and persistent low achievement in mathematics. *Journal of Developmental and Behavioral Pediatrics*, 32(3), 250–263. <https://doi.org/10.1097/DBP.0b013e318209edef>
- Gibbs, B. G., & Heaton, T. B. (2014). Drop out from primary to secondary school in mexico: A life course perspective. *International Journal of Educational Development*, 36, 63–71. <https://doi.org/10.1016/j.ijedudev.2013.11.005>

- Goddard, R. D., Sweetland, S. R., & Hoy, W. K. (2000). Academic emphasis of urban elementary schools and student achievement in reading and mathematics: A multilevel analysis. *Educational Administration Quarterly*, 36(5), 683–702.
<https://doi.org/10.1177/00131610021969164>
- Golding, J., Gregory, S., Ellis, G., Nunes, T., Bryant, P., Iles-Caven, Y., & Nowicki, S. (2019). Maternal prenatal external locus of control and reduced mathematical and science abilities in their offspring: A longitudinal birth cohort study. *Frontiers in Psychology*, 10, 194. <https://doi.org/10.3389/fpsyg.2019.00194>
- Golombok, S., & Rust, J. (1993). The pre-school activities inventory: A standardized assessment of gender role in children. *Psychological Assessment*, 5(2), 131–136.
<https://doi.org/10.1037/1040-3590.5.2.131>
- Golombok, S., Rust, J., Zervoulis, K., Croudace, T., Golding, J., & Hines, M. (2008). Developmental trajectories of sex-typed behavior in boys and girls: A longitudinal general population study of children aged 2.5–8 years. *Child Development*, 79(5), 1583–1593. <https://doi.org/10.1111/j.1467-8624.2008.01207.x>
- Goodman, R. (1997). The strengths and difficulties questionnaire: A research note. *Journal of Child Psychology and Psychiatry*, 38(5), 581–586.
<https://doi.org/10.1111/j.1469-7610.1997.tb01545.x>
- Goodman, R. (2001). Psychometric properties of the strengths and difficulties questionnaire. *Journal of the American Academy of Child & Adolescent*

Psychiatry, 40(11), 1337–1345. <https://doi.org/10.1097/00004583-200111000-00015>

Gorard, S., & See, B. H. (2013). *Do parental involvement interventions increase attainment? A review of the evidence*. London: Nuffield Foundation.

Gottfredson, L. S. (2004). Intelligence: Is it the epidemiologists' elusive "fundamental cause" of social class inequalities in health? *Journal of Personality and Social Psychology*, 86(1), 174–199. <https://doi.org/10.1037/0022-3514.86.1.174>

Green, H., McGinnity, Á., Meltzer, H., Ford, T., & Goodman, R. (2005). *Mental health of children and young people in great britain, 2004*. Basingstoke: Palgrave Macmillan.

Grills-Tauechel, A. E., Norton, P., & Ollendick, T. H. (2010). A longitudinal examination of factors predicting anxiety during the transition to middle school. *Anxiety, Stress, & Coping*, 23(5), 493–513. <https://doi.org/10.1080/10615800903494127>

Gunderson, E. A., Ramirez, G., Levine, S. C., & Beilock, S. L. (2012). The role of parents and teachers in the development of gender-related math attitudes. *Sex Roles*, 66(3-4), 153–166. <https://doi.org/10.1007/s11199-011-9996-2>

Gutman, L. M., & Midgley, C. (2000). The role of protective factors in supporting the academic achievement of poor african american students during the middle school transition. *Journal of Youth and Adolescence*, 29(2), 223–249. <https://doi.org/10.1023/A:1005108700243>

- Hadden, I. R., Easterbrook, M. J., Nieuwenhuis, M., Fox, K. J., & Dolan, P. (2020). Self-affirmation reduces the socioeconomic attainment gap in schools in England. *British Journal of Educational Psychology*, 90(2), 517–536.
<https://doi.org/10.1111/bjep.12291>
- Hadwin, J. A., Brogan, J., & Stevenson, J. (2005). State anxiety and working memory in children: A test of processing efficiency theory. *Educational Psychology*, 25(4), 379–393. <https://doi.org/10.1080/01443410500041607>
- Hadwin, J. A., & Field, A. P. (2010). *Information processing biases and anxiety: A developmental perspective*. Chichester: Wiley-Blackwell.
- Hall, G. E., & DiPerna, J. C. (2017). Childhood social skills as predictors of middle school academic adjustment. *The Journal of Early Adolescence*, 37(6), 825–851.
<https://doi.org/10.1177/0272431615624566>
- Hannigan, L., Walaker, N., Waszczuk, M., McAdams, T., & Eley, T. (2017). Aetiological influences on stability and change in emotional and behavioural problems across development: A systematic review. *Psychopathology Review*, 4(1), 52–108. <https://doi.org/10.5127/pr.038315>
- Hart, S. A., Logan, J. A., Thompson, L., Kovas, Y., McLoughlin, G., & Petrill, S. A. (2016). A latent profile analysis of math achievement, numerosity, and math anxiety in twins. *Journal of Educational Psychology*, 108(2), 181–193.
<https://doi.org/10.1037/edu0000045>

- Harter, S. (1981). A new self-report scale of intrinsic versus extrinsic orientation in the classroom: Motivational and informational components. *Developmental Psychology*, 17(3), 300–312. <https://doi.org/10.1037/0012-1649.17.3.300>
- Harter, S., Whitesell, N. R., & Kowalski, P. (1992). Individual differences in the effects of educational transitions on young adolescent's perceptions of competence and motivational orientation. *American Educational Research Journal*, 29(4), 777–807. <https://doi.org/10.3102/00028312029004777>
- Haworth, C. M., Davis, O. S., & Plomin, R. (2013). Twins early development study (teds): A genetically sensitive investigation of cognitive and behavioral development from childhood to young adulthood. *Twin Research and Human Genetics*, 16(1), 117–125. <https://doi.org/10.1017/thg.2012.91>
- Haworth, C. M., Harlaar, N., Kovas, Y., Davis, O. S., Oliver, B. R., Hayiou-Thomas, M. E., ... others. (2007). Internet cognitive testing of large samples needed in genetic research. *Twin Research and Human Genetics*, 10(4), 554–563. <https://doi.org/10.1375/twin.10.4.554>
- Haworth, C. M., Kovas, Y., Petrill, S. A., & Plomin, R. (2007). Developmental origins of low mathematics performance and normal variation in twins from 7 to 9 years. *Twin Research and Human Genetics*, 10(1), 106–117. <https://doi.org/10.1375/twin.10.1.106>
- Hay, D. F., Pawlby, S., Sharp, D., Asten, P., Mills, A., & Kumar, R. (2001). Intellectual problems shown by 11-year-old children whose mothers had postnatal

depression. *Journal of Child Psychology and Psychiatry*, 42(7), 871–889.

<https://doi.org/10.1111/1469-7610.00784>

Heck, R. H. (2000). Examining the impact of school quality on school outcomes and improvement: A value-added approach. *Educational Administration Quarterly*, 36(4), 513–552. <https://doi.org/10.1177/00131610021969092>

Helsen, M., Vollebergh, W., & Meeus, W. (2000). Social support from parents and friends and emotional problems in adolescence. *Journal of Youth and Adolescence*, 29(3), 319–335. <https://doi.org/10.1023/A:1005147708827>

Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal for Research in Mathematics Education*, 21, 33–46. <https://doi.org/10.2307/749455>

Henry, K. L., Knight, K. E., & Thornberry, T. P. (2012). School disengagement as a predictor of dropout, delinquency, and problem substance use during adolescence and early adulthood. *Journal of Youth and Adolescence*, 41(2), 156–166. <https://doi.org/10.1007/s10964-011-9665-3>

Higgins, S., & Katsipatakis, M. (2015). Evidence from meta-analysis about parental involvement in education which supports their children's learning. *Journal of Children's Services*, 10(3), 280–290. <https://doi.org/10.1108/JCS-02-2015-0009>

Hill, F., Mammarella, I. C., Devine, A., Caviola, S., Passolunghi, M. C., & Szűcs, D. (2016). Maths anxiety in primary and secondary school students: Gender differences, developmental changes and anxiety specificity. *Learning and Individual Differences*, 48, 45–53. <https://doi.org/10.1016/j.lindif.2016.02.006>

- Hill, N. E., Castellino, D. R., Lansford, J. E., Nowlin, P., Dodge, K. A., Bates, J. E., & Pettit, G. S. (2004). Parent academic involvement as related to school behavior, achievement, and aspirations: Demographic variations across adolescence. *Child Development*, 75(5), 1491–1509. <https://doi.org/10.1111/j.1467-8624.2004.00753.x>
- Hirsch, B. J., & Rapkin, B. D. (1987). The transition to junior high school: A longitudinal study of self-esteem, psychological symptomatology, school life, and social support. *Child Development*, 58(5), 1235–1243. <https://doi.org/10.1111/j.1467-8624.1987.tb01454.x>.
- Hitch, G. J., Halliday, S., Schaafstal, A. M., & Schraagen, J. M. C. (1988). Visual working memory in young children. *Memory & Cognition*, 16(2), 120–132. <https://doi.org/10.3758/BF03197067>
- Hoard, M. K., Geary, D. C., Byrd-Craven, J., & Nugent, L. (2008). Mathematical cognition in intellectually precocious first graders. *Developmental Neuropsychology*, 33(3), 251–276. <https://doi.org/10.1080/87565640801982338>
- Holmes, J., & Adams, J. W. (2006). Working memory and children's mathematical skills: Implications for mathematical development and mathematics curricula. *Educational Psychology*, 26(3), 339–366. <https://doi.org/10.1080/01443410500341056>
- Honaker, J., King, G., & Blackwell, M. (2011). Amelia II: A program for missing data. *Journal of Statistical Software*, 45(7), 1–47. Retrieved from <http://www.jstatsoft.org/v45/i07/>

- Hopko, D. R., Mahadevan, R., Bare, R. L., & Hunt, M. K. (2003). The abbreviated math anxiety scale (amas): Construction, validity, and reliability. *Assessment, 10*(2), 178–182. <https://doi.org/10.1177/1073191103010002008>
- Hughes, J. N., & Cao, Q. (2018). Trajectories of teacher-student warmth and conflict at the transition to middle school: Effects on academic engagement and achievement. *Journal of School Psychology, 67*, 148–162. <https://doi.org/10.1016/j.jsp.2017.10.003>
- Hughes, L. A., Banks, P., & Terras, M. M. (2013). Secondary school transition for children with special educational needs: A literature review. *Support for Learning, 28*(1), 24–34. <https://doi.org/10.1111/1467-9604.12012>
- Huntsinger, C. S., Jose, P. E., & Luo, Z. (2016). Parental facilitation of early mathematics and reading skills and knowledge through encouragement of home-based activities. *Early Childhood Research Quarterly, 37*, 1–15. <https://doi.org/10.1016/j.ecresq.2016.02.005>
- Hyde, J. S., Fennema, E., & Lamon, S. J. (1990). Gender differences in mathematics performance: A meta-analysis. *Psychological Bulletin, 107*(2), 139–155. <https://doi.org/10.1037/0033-2909.107.2.139>
- Ialongo, N., Edelsohn, G., Werthamer-Larsson, L., Crockett, L., & Kellam, S. (1994). The significance of self-reported anxious symptoms in first-grade children. *Journal of Abnormal Child Psychology, 22*(4), 441–455. <https://doi.org/10.1007/BF02168084>

- Ialongo, N. S., Edelsohn, G., & Kellam, S. G. (2001). A further look at the prognostic power of young children's reports of depressed mood and feelings. *Child Development*, 72(3), 736–747. <https://doi.org/10.1111/1467-8624.00312>
- Imbo, I., & Vandierendonck, A. (2007). The development of strategy use in elementary school children: Working memory and individual differences. *Journal of Experimental Child Psychology*, 96(4), 284–309. <https://doi.org/10.1016/j.jecp.2006.09.001>
- Isbell, E., Fukuda, K., Neville, H. J., & Vogel, E. K. (2015). Visual working memory continues to develop through adolescence. *Frontiers in Psychology*, 6, 696. <https://doi.org/10.3389/fpsyg.2015.00696>
- Izard, V., Sann, C., Spelke, E. S., & Streri, A. (2009). Newborn infants perceive abstract numbers. *Proceedings of the National Academy of Sciences*, 106(25), 10382–10385. <https://doi.org/10.1073/pnas.0812142106>
- Jacobs, J. E., & Bleeker, M. M. (2004). Girls' and boys' developing interests in math and science: Do parents matter? *New Directions for Child and Adolescent Development*, 106, 5–21. <https://doi.org/10.1002/cd.113>
- Jaekel, J., Wolke, D., & Chernova, J. (2012). Mother and child behaviour in very preterm and term dyads at 6 and 8 years. *Developmental Medicine & Child Neurology*, 54(8), 716–723. <https://doi.org/10.1111/j.1469-8749.2012.04323.x>
- Jamshidian, M., & Jalal, S. (2010). Tests of homoscedasticity, normality, and missing completely at random for incomplete multivariate data. *Psychometrika*, 75(4), 649–674. <https://doi.org/10.1007/s11336-010-9175-3>

- Jamshidian, M., Jalal, S., & Jansen, C. (2014). MissMech: An R package for testing homoscedasticity, multivariate normality, and missing completely at random (mcar). *Journal of Statistical Software*, 56(6), 1–31. Retrieved from <http://www.jstatsoft.org/v56/i06/>
- Jansen, B. R., Schmitz, E. A., & Maas, H. L. van der. (2016). Affective and motivational factors mediate the relation between math skills and use of math in everyday life. *Frontiers in Psychology*, 7, 513. <https://doi.org/10.3389/fpsyg.2016.00513>
- Jeynes, W. H. (2007). The relationship between parental involvement and urban secondary school student academic achievement: A meta-analysis. *Urban Education*, 42(1), 82–110. <https://doi.org/10.1177/0042085906293818>
- Jia, Y., Way, N., Ling, G., Yoshikawa, H., Chen, X., Hughes, D., ... Lu, Z. (2009). The influence of student perceptions of school climate on socioemotional and academic adjustment: A comparison of chinese and american adolescents. *Child Development*, 80(5), 1514–1530. <https://doi.org/10.1111/j.1467-8624.2009.01348.x>
- Jimenez, M. E., Wade, R., Lin, Y., Morrow, L. M., & Reichman, N. E. (2016). Adverse experiences in early childhood and kindergarten outcomes. *Pediatrics*, 137(2), e20151839. <https://doi.org/10.1542/peds.2015-1839>
- Jindal-Snape, D., Hannah, E. F., Cantali, D., Barlow, W., & MacGillivray, S. (2020). Systematic literature review of primary–secondary transitions: International research. *Review of Education*, 8(2), 526–566. <https://doi.org/10.1002/rev3.3197>

- Johnson, D. W., Maruyama, G., Johnson, R., Nelson, D., & Skon, L. (1981). Effects of cooperative, competitive, and individualistic goal structures on achievement: A meta-analysis. *Psychological Bulletin*, 89(1), 47–62.
<https://doi.org/10.1037/0033-2909.89.1.47>
- Johnston-Wilder, S., Brindley, J., & Dent, P. (2014). *A survey of mathematics anxiety and mathematical resilience among existing apprentices*. London: Gatsby Charitable Foundation. Retrieved from <http://wrap.warwick.ac.uk/73857/>
- Jordan, N. C., Kaplan, D., Locuniak, M. N., & Ramineni, C. (2007). Predicting first-grade math achievement from developmental number sense trajectories. *Learning Disabilities Research & Practice*, 22(1), 36–46.
<https://doi.org/10.1111/j.1540-5826.2007.00229.x>
- Jordan, N. C., Kaplan, D., Ramineni, C., & Locuniak, M. N. (2009). Early math matters: Kindergarten number competence and later mathematics outcomes. *Developmental Psychology*, 45(3), 850–867. <https://doi.org/10.1037/a0014939>
- Jorgensen, T. D., Pornprasertmanit, S., Schoemann, A. M., & Yves, R. (2018). *semTools: Useful tools for structural equation modeling*. Retrieved from <https://CRAN.R-project.org/package=semTools>
- Joussemet, M., Koestner, R., Lekes, N., & Landry, R. (2005). A longitudinal study of the relationship of maternal autonomy support to children's adjustment and achievement in school. *Journal of Personality*, 73(5), 1215–1236.
<https://doi.org/10.1111/j.1467-6494.2005.00347.x>

Kaplan, A., & Maehr, M. L. (2007). The contributions and prospects of goal orientation theory. *Educational Psychology Review*, 19(2), 141–184.

<https://doi.org/10.1007/s10648-006-9012-5>

Kaplan, E., Fein, D., Kramer, J., Delis, D., & Morris, R. (1999). *WISC-III as a Process Instrument (WISC-III-PI)*. New York: The Psychological Corporation.

Kasen, S., Cohen, P., & Brook, J. S. (1998). Adolescent school experiences and dropout, adolescent pregnancy, and young adult deviant behavior. *Journal of Adolescent Research*, 13(1), 49–72. <https://doi.org/10.1177/0743554898131004>

Keller, H. (2016). Psychological autonomy and hierarchical relatedness as organizers of developmental pathways. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 371(1686), 20150070.

<https://doi.org/10.1098/rstb.2015.0070>

Kessler, R. C., Berglund, P., Demler, O., Jin, R., Merikangas, K. R., & Walters, E. E. (2005). Lifetime prevalence and age-of-onset distributions of dsm-iv disorders in the national comorbidity survey replication. *Archives of General Psychiatry*, 62(6), 593–602. <https://doi.org/10.1001/archpsyc.62.6.593>

Kessler, R. C., Foster, C. L., Saunders, W. B., & Stang, P. E. (1995). Social consequences of psychiatric disorders, i: Educational attainment. *American Journal of Psychiatry*, 152(7), 1026–1032.

<https://doi.org/10.1176/ajp.152.7.1026>

Khambati, N., Mahedy, L., Heron, J., & Emond, A. (2018). Educational and emotional health outcomes in adolescence following maltreatment in early childhood: A

- population-based study of protective factors. *Child Abuse & Neglect*, 81, 343–353. <https://doi.org/10.1016/j.chiabu.2018.05.008>
- Kim, H. Y., Schwartz, K., Cappella, E., & Seidman, E. (2014). Navigating middle grades: Role of social contexts in middle grade school climate. *American Journal of Community Psychology*, 54(1-2), 28–45. <https://doi.org/10.1007/s10464-014-9659-x>
- Kim-Cohen, J., Caspi, A., Moffitt, T. E., Harrington, H., Milne, B. J., & Poulton, R. (2003). Prior juvenile diagnoses in adults with mental disorder: Developmental follow-back of a prospective-longitudinal cohort. *Archives of General Psychiatry*, 60(7), 709–717. <https://doi.org/10.1001/archpsyc.60.7.709>
- Kingery, J. N., Erdley, C. A., & Marshall, K. C. (2011). Peer acceptance and friendship as predictors of early adolescents' adjustment across the middle school transition. *Merrill-Palmer Quarterly (1982-)*, 57(3), 215–243.
- Koenig, L. J., & Gladstone, T. R. (1998). Pubertal development and school transition: Joint influences on depressive symptoms in middle and late adolescents. *Behavior Modification*, 22(3), 335–357. <https://doi.org/10.1177/01454455980223008>
- Konishi, C., Hymel, S., Zumbo, B. D., & Li, Z. (2010). Do school bullying and student—teacher relationships matter for academic achievement? A multilevel analysis. *Canadian Journal of School Psychology*, 25(1), 19–39. <https://doi.org/10.1177/0829573509357550>

- Kovas, Y., Haworth, C. M., Dale, P. S., Plomin, R., Weinberg, R. A., Thomson, J. M., & Fischer, K. W. (2007). The genetic and environmental origins of learning abilities and disabilities in the early school years. *Monographs of the Society for Research in Child Development*, 72(3), 1–144. <https://doi.org/10.1111/j.1540-5834.2007.00439.x>.
- Kovas, Y., Voronin, I., Kaydalov, A., Malykh, S. B., Dale, P. S., & Plomin, R. (2013). Literacy and numeracy are more heritable than intelligence in primary school. *Psychological Science*, 24(10), 2048–2056. <https://doi.org/10.1177/0956797613486982>
- Lambe, M., Hultman, C., Torrång, A., MacCabe, J., & Cnattingius, S. (2006). Maternal smoking during pregnancy and school performance at age 15. *Epidemiology*, 17(5), 524–530. <https://doi.org/10.1097/01.ede.0000231561.49208.be>
- Last, C. G., & Strauss, C. C. (1990). School refusal in anxiety-disordered children and adolescents. *Journal of the American Academy of Child & Adolescent Psychiatry*, 29(1), 31–35. <https://doi.org/10.1097/00004583-199001000-00006>
- Lee, P. A. (1980). Normal ages of pubertal events among american males and females. *Journal of Adolescent Health Care*, 1(1), 26–29. [https://doi.org/10.1016/S0197-0070\(80\)80005-2](https://doi.org/10.1016/S0197-0070(80)80005-2)
- LeFevre, J.-A., Skwarchuk, S.-L., Smith-Chant, B. L., Fast, L., Kamawar, D., & Bisanz, J. (2009). Home numeracy experiences and children's math performance in the early school years. *Canadian Journal of Behavioural Science/Revue Canadienne Des Sciences Du Comportement*, 41(2), 55–66. <https://doi.org/10.1037/a0014532>

- Lenhart, A., Purcell, K., Smith, A., & Zickuhr, K. (2010). *Social media & mobile internet use among teens and young adults*. USA: Pew Research Center.
Retrieved from <https://files.eric.ed.gov/fulltext/ED525056.pdf>
- Lester, K. J., Lisk, S. C., Carr, E., Patrick, F., & Eley, T. C. (2019). Associations between attentional bias and interpretation bias and change in school concerns and anxiety symptoms during the transition from primary to secondary school. *Journal of Abnormal Child Psychology*, 47(9), 1521–1532.
<https://doi.org/10.1007/s10802-019-00528-3>
- Lester, L., & Cross, D. (2015). The relationship between school climate and mental and emotional wellbeing over the transition from primary to secondary school. *Psychology of Well-Being*, 5(1), 9. <https://doi.org/10.1186/s13612-015-0037-8>
- Levens, S. M., Muhtadie, L., & Gotlib, I. H. (2009). Rumination and impaired resource allocation in depression. *Journal of Abnormal Psychology*, 118(4), 757–766.
<https://doi.org/10.1037/a0017206>
- Lindberg, S. M., Hyde, J. S., Petersen, J. L., & Linn, M. C. (2010). New trends in gender and mathematics performance: A meta-analysis. *Psychological Bulletin*, 136(6), 1123–1135. <https://doi.org/10.1037/a0021276>
- Lucey, H., & Reay, D. (2000). Identities in transition: Anxiety and excitement in the move to secondary school. *Oxford Review of Education*, 26(2), 191–205.
<https://doi.org/10.1080/713688522>

- Ma, X. (1999). A meta-analysis of the relationship between anxiety toward mathematics and achievement in mathematics. *Journal for Research in Mathematics Education*, 30(5), 520–540. <https://doi.org/10.2307/749772>
- Ma, X., & Xu, J. (2004). The causal ordering of mathematics anxiety and mathematics achievement: A longitudinal panel analysis. *Journal of Adolescence*, 27(2), 165–179. <https://doi.org/10.1016/j.adolescence.2003.11.003>
- Madjar, N., & Chohat, R. (2017). Will i succeed in middle school? A longitudinal analysis of self-efficacy in school transitions in relation to goal structures and engagement. *Educational Psychology*, 37(6), 680–694. <https://doi.org/10.1080/01443410.2016.1179265>
- Madjar, N., Cohen, V., & Shoval, G. (2018a). Longitudinal analysis of the trajectories of academic and social motivation across the transition from elementary to middle school. *Educational Psychology*, 38(2), 221–247. <https://doi.org/10.1080/01443410.2017.1341623>
- Madjar, N., Zalsman, G., Weizman, A., Lev-Ran, S., & Shoval, G. (2018b). Predictors of developing mathematics anxiety among middle-school students: A 2-year prospective study. *International Journal of Psychology*, 53(6), 426–432. <https://doi.org/10.1002/ijop.12403>
- Maher, D. (2010). Supporting students' transition from primary school to high school using the internet as a communication tool. *Technology, Pedagogy and Education*, 19(1), 17–30. <https://doi.org/10.1080/14759390903579216>

- Malanchini, M., Rimfeld, K., Shakeshaft, N. G., Rodic, M., Schofield, K., Selzam, S., ... Kovas, Y. (2017). The genetic and environmental aetiology of spatial, mathematics and general anxiety. *Scientific Reports*, 7, 42218.
<https://doi.org/10.1038/srep42218>
- Maloney, E. A. (2016). Math Anxiety: Causes, Consequences, and Remediation. In K. R. Wentzel & D. B. Miele (Eds.), *Handbook of motivation at school* (2nd ed., pp. 408–423). New York: Routledge. <https://doi.org/10.4324/9781315773384>
- Maloney, E. A., Ansari, D., & Fugelsang, J. A. (2011). The effect of mathematics anxiety on the processing of numerical magnitude. *Quarterly Journal of Experimental Psychology*, 64(1), 10–16.
<https://doi.org/10.1080/17470218.2010.533278>
- Maloney, E. A., & Beilock, S. L. (2012). Math anxiety: Who has it, why it develops, and how to guard against it. *Trends in Cognitive Sciences*, 16(8), 404–406.
<https://doi.org/10.1016/j.tics.2012.06.008>
- Maloney, E. A., Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2015). Intergenerational effects of parents' math anxiety on children's math achievement and anxiety. *Psychological Science*, 26(9), 1480–1488.
<https://doi.org/10.1177/0956797615592630>
- Maloney, E. A., Risko, E. F., Ansari, D., & Fugelsang, J. (2010). Mathematics anxiety affects counting but not subitizing during visual enumeration. *Cognition*, 114(2), 293–297. <https://doi.org/10.1016/j.cognition.2009.09.013>

- Maloney, E. A., Schaeffer, M. W., & Beilock, S. L. (2013). Mathematics anxiety and stereotype threat: Shared mechanisms, negative consequences and promising interventions. *Research in Mathematics Education*, 15(2), 115–128.
<https://doi.org/10.1080/14794802.2013.797744>
- Maltais, C., Duchesne, S., Ratelle, C. F., & Feng, B. (2015). Attachment to the mother and achievement goal orientations at the beginning of middle school: The mediating role of academic competence and anxiety. *Learning and Individual Differences*, 39, 39–48. <https://doi.org/10.1016/j.lindif.2015.03.006>
- Maltais, C., Duchesne, S., Ratelle, C. F., & Feng, B. (2017). Learning climate, academic competence, and anxiety during the transition to middle school: Parental attachment as a protective factor. *European Review of Applied Psychology*, 67(2), 103–112. <https://doi.org/10.1016/j.erap.2017.01.002>
- Malti, T., McDonald, K., Rubin, K. H., Rose-Krasnor, L., & Booth-LaForce, C. (2015). Developmental trajectories of peer-reported aggressive behavior: The role of friendship understanding, friendship quality, and friends' aggressive behavior. *Psychology of Violence*, 5(4), 402–410. <https://doi.org/10.1037/a0039685>
- Manolitsis, G., Georgiou, G. K., & Tziraki, N. (2013). Examining the effects of home literacy and numeracy environment on early reading and math acquisition. *Early Childhood Research Quarterly*, 28(4), 692–703.
<https://doi.org/10.1016/j.ecresq.2013.05.004>
- Marcotte, D., Lévesque, N., & Fortin, L. (2006). Variations of cognitive distortions and school performance in depressed and non-depressed high school adolescents: A

two-year longitudinal study. *Cognitive Therapy and Research*, 30(2), 211–225.

<https://doi.org/10.1007/s10608-006-9020-2>

Marsh, H. W. (1989). Age and sex effects in multiple dimensions of self-concept:

Preadolescence to early adulthood. *Journal of Educational Psychology*, 81(3),

417–430. <https://doi.org/10.1037/0022-0663.81.3.417>

Marsh, H. W., & Craven, R. G. (2006). Reciprocal effects of self-concept and

performance from a multidimensional perspective: Beyond seductive pleasure

and unidimensional perspectives. *Perspectives on Psychological Science*, 1(2),

133–163. <https://doi.org/10.1111/j.1745-6916.2006.00010.x>

Marsh, H. W., Craven, R. G., & Debus, R. (1991). Self-concepts of young children 5 to

8 years of age: Measurement and multidimensional structure. *Journal of*

Educational Psychology, 83(3), 377–392. [https://doi.org/10.1037/0022-](https://doi.org/10.1037/0022-0663.83.3.377)

[0663.83.3.377](https://doi.org/10.1037/0022-0663.83.3.377)

Martínez, R. S., Aricak, O. T., Graves, M. N., Peters-Myszak, J., & Nellis, L. (2011).

Changes in perceived social support and socioemotional adjustment across the

elementary to junior high school transition. *Journal of Youth and Adolescence*,

40(5), 519–530. <https://doi.org/10.1007/s10964-010-9572-z>

Mathews, A., & MacLeod, C. (2005). Cognitive vulnerability to emotional disorders.

Annu. Rev. Clin. Psychol., 1, 167–195.

<https://doi.org/10.1146/annurev.clinpsy.1.102803.143916>

Maxwell, S., Reynolds, K. J., Lee, E., Subasic, E., & Bromhead, D. (2017). The impact

of school climate and school identification on academic achievement: Multilevel

modeling with student and teacher data. *Frontiers in Psychology*, 8, 2069.

<https://doi.org/10.3389/fpsyg.2017.02069>

McKenna, J. S., & Nickols, S. Y. (1988). Planning for retirement security: What helps or hinders women in the middle years? *Home Economics Research Journal*, 17(2), 153–164. <https://doi.org/10.1177/1077727X8801700204>

McKenzie, B., Bull, R., & Gray, C. (2003). The effects of phonological and visual-spatial interference on children's arithmetical performance. *Educational and Child Psychology*, 20(3), 93–108.

McLaughlin, C., & Clarke, B. (2010). Relational matters: A review of the impact of school experience on mental health in early adolescence. *Educational and Child Psychology*, 27(1), 91–103.

McLean, C. P., & Anderson, E. R. (2009). Brave men and timid women? A review of the gender differences in fear and anxiety. *Clinical Psychology Review*, 29(6), 496–505. <https://doi.org/10.1016/j.cpr.2009.05.003>

McLean, L., & Connor, C. M. (2015). Depressive symptoms in third-grade teachers: Relations to classroom quality and student achievement. *Child Development*, 86(3), 945–954. <https://doi.org/10.1111/cdev.12344>

McLean, L., & Connor, C. M. (2018). Relations between third grade teachers' depressive symptoms and their feedback to students, with implications for student mathematics achievement. *School Psychology Quarterly*, 33(2), 272–282. <https://doi.org/10.1037/spq0000225>

- McLeod, J. D., & Kaiser, K. (2004). Childhood emotional and behavioral problems and educational attainment. *American Sociological Review*, 69(5), 636–658.
<https://doi.org/10.1177/000312240406900502>
- McLoyd, V. C. (1998). Socioeconomic disadvantage and child development. *American Psychologist*, 53(2), 185–204. <https://doi.org/10.1037/0003-066X.53.2.185>
- McMullan, M., Jones, R., & Lea, S. (2012). Math anxiety, self-efficacy, and ability in british undergraduate nursing students. *Research in Nursing & Health*, 35(2), 178–186. <https://doi.org/10.1002/nur.21460>
- McQuiggan, M., & Megra, M. (2017). *Parent and family involvement in education: Results from the national household education surveys program of 2016. NCES 2017-102*. Washington: U.S. Department of Education. Retrieved from <http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2017102>
- Meece, J. L., Anderman, E. M., & Anderman, L. H. (2006). Classroom goal structure, student motivation, and academic achievement. *Annu. Rev. Psychol.*, 57, 487–503. <https://doi.org/10.1146/annurev.psych.56.091103.070258>
- Melby-Lervåg, M., & Hulme, C. (2013). Is working memory training effective? A meta-analytic review. *Developmental Psychology*, 49(2), 270–291.
<https://doi.org/10.1037/a0028228>
- Meltzer, H., Gatward, R., Goodman, R., & Ford, T. (2000). *The mental health of children and adolescents in great britain*. London: Stationery Office.

- Mensah, F. K., & Kiernan, K. E. (2010). Parents' mental health and children's cognitive and social development. *Social Psychiatry and Psychiatric Epidemiology*, 45(11), 1023–1035. <https://doi.org/10.1007/s00127-009-0137-y>
- Merikangas, K. R., He, J.-p., Burstein, M., Swanson, S. A., Avenevoli, S., Cui, L., ... Swendsen, J. (2010). Lifetime prevalence of mental disorders in us adolescents: Results from the national comorbidity survey replication–adolescent supplement (ncs-a). *Journal of the American Academy of Child & Adolescent Psychiatry*, 49(10), 980–989. <https://doi.org/10.1016/j.jaac.2010.05.017>
- Midgley, C., Anderman, E., & Hicks, L. (1995). Differences between elementary and middle school teachers and students: A goal theory approach. *The Journal of Early Adolescence*, 15(1), 90–113.
<https://doi.org/10.1177/0272431695015001006>
- Midgley, C., Feldlaufer, H., & Eccles, J. S. (1989a). Change in teacher efficacy and student self-and task-related beliefs in mathematics during the transition to junior high school. *Journal of Educational Psychology*, 81(2), 247–258.
<https://doi.org/10.1037/0022-0663.81.2.247>
- Midgley, C., Feldlaufer, H., & Eccles, J. S. (1989b). Student/teacher relations and attitudes toward mathematics before and after the transition to junior high school. *Child Development*, 60, 981–992. <https://doi.org/10.1111/j.1467-8624.1989.tb03529.x>

- Mineka, S., & Zinbarg, R. (2006). A contemporary learning theory perspective on the etiology of anxiety disorders: It's not what you thought it was. *American Psychologist*, 61(1), 10–26. <https://doi.org/10.1037/0003-066X.61.1.10>
- Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: A latent variable analysis. *Cognitive Psychology*, 41(1), 49–100. [https://doi.org/10.1016/S0010-0285\(02\)00537-6](https://doi.org/10.1016/S0010-0285(02)00537-6)
- Moran, T. P. (2016). Anxiety and working memory capacity: A meta-analysis and narrative review. *Psychological Bulletin*, 142(8), 831–864. <https://doi.org/10.1037/bul0000051>
- Mundy, L. K., Canterford, L., Kosola, S., Degenhardt, L., Allen, N. B., & Patton, G. C. (2017). Peer victimization and academic performance in primary school children. *Academic Pediatrics*, 17(8), 830–836. <https://doi.org/10.1016/j.acap.2017.06.012>
- Muris, P., & Ollendick, T. H. (2005). The role of temperament in the etiology of child psychopathology. *Clinical Child and Family Psychology Review*, 8(4), 271–289. <https://doi.org/10.1007/s10567-005-8809-y>
- Murray-Close, D., Ostrov, J. M., & Crick, N. R. (2007). A short-term longitudinal study of growth of relational aggression during middle childhood: Associations with gender, friendship intimacy, and internalizing problems. *Development and Psychopathology*, 19(1), 187–203. <https://doi.org/10.1017/S0954579407070101>
- Namkung, J. M., Peng, P., & Lin, X. (2019). The relation between mathematics anxiety and mathematics performance among school-aged students: A meta-analysis.

Review of Educational Research, 89(3), 459–496.

<https://doi.org/10.3102/0034654319843494>

Napoli, A. R., & Purpura, D. J. (2018). The home literacy and numeracy environment in preschool: Cross-domain relations of parent–child practices and child outcomes. *Journal of Experimental Child Psychology*, 166, 581–603.

<https://doi.org/10.1016/j.jecp.2017.10.002>

National Institute of Child Health and Human Development Early Child Care Research Network. (2008). Mothers’ and fathers’ support for child autonomy and early school achievement. *Developmental Psychology*, 44(4), 895–907.

<https://doi.org/10.1037/0012-1649.44.4.895>

National Numeracy. (2018). The Essentials of Numeracy: A new approach to making the UK numerate. Retrieved from

https://www.nationalnumeracy.org.uk/sites/default/files/nn124_essentials_numeracyreport_for_web.pdf

National Numeracy. (2019). What is numeracy? Retrieved from

<https://www.nationalnumeracy.org.uk/what-numeracy>

Neal, S., Rice, F., Ng-Knight, T., Riglin, L., & Frederickson, N. (2016). Exploring the longitudinal association between interventions to support the transition to secondary school and child anxiety. *Journal of Adolescence*, 50, 31–43.

<https://doi.org/10.1016/j.adolescence.2016.04.003>

- Nelson, G., & Powell, S. R. (2018). A systematic review of longitudinal studies of mathematics difficulty. *Journal of Learning Disabilities*, 51(6), 523–539.
<https://doi.org/10.1177/0022219417714773>
- Netsi, E., Pearson, R. M., Murray, L., Cooper, P., Craske, M. G., & Stein, A. (2018). Association of persistent and severe postnatal depression with child outcomes. *JAMA Psychiatry*, 75(3), 247–253.
<https://doi.org/10.1001/jamapsychiatry.2017.4363>
- Newman, B. M., Newman, P. R., Griffen, S., O'Connor, K., & Spas, J. (2007). The relationship of social support to depressive symptoms during the transition to high school. *Adolescence*, 42(167), 441–459.
- Ng-Knight, T., Shelton, K. H., Riglin, L., McManus, I., Frederickson, N., & Rice, F. (2016). A longitudinal study of self-control at the transition to secondary school: Considering the role of pubertal status and parenting. *Journal of Adolescence*, 50, 44–55. <https://doi.org/10.1016/j.adolescence.2016.04.006>
- Nielsen, L., Shaw, T., Meilstrup, C., Koushede, V., Bendtsen, P., Rasmussen, M., ... Cross, D. (2017). School transition and mental health among adolescents: A comparative study of school systems in denmark and australia. *International Journal of Educational Research*, 83, 65–74.
<https://doi.org/10.1016/j.ijer.2017.01.011>
- Nigg, J. T. (2006). Temperament and developmental psychopathology. *Journal of Child Psychology and Psychiatry*, 47(3-4), 395–422. <https://doi.org/10.1111/j.1469-7610.2006.01612.x>

- Nottelmann, E. D. (1987). Competence and self-esteem during transition from childhood to adolescence. *Developmental Psychology*, 23(3), 441–450.
<https://doi.org/10.1037/0012-1649.23.3.441>
- NRDC. (2013). *The impact of poor numeracy skills on adults, research review*. London: Institute of Education (IOE), University of London. Retrieved from https://maths4us.files.wordpress.com/2013/08/nrdc_impacts-of-numeracy-review_june13-m4u.pdf
- Núñez-Peña, M. I., & Suárez-Pellicioni, M. (2014). Less precise representation of numerical magnitude in high math-anxious individuals: An erp study of the size and distance effects. *Biological Psychology*, 103, 176–183.
<https://doi.org/10.1016/j.biopsycho.2014.09.004>
- OECD. (2013). *PISA 2012 results: Ready to learn (volume III)*. Paris: OECD Publishing.
- OECD. (2014). *PISA 2012 Results: What Students Know and Can Do (Volume I, Revised edition, February 2014): Student Performance in Mathematics, Reading and Science*. Paris: OECD Publishing.
- OECD. (2016a). *PISA 2015 Results (Volume I): Excellence and Equity in Education*. Paris: OECD Publishing.
- OECD. (2016b). *PISA 2015 Results (Volume II): Policies and Practices for Successful Schools*. Paris: OECD Publishing.
- Ofcom. (2017). *Children and parents: Media use and attitudes report*. London: Ofcom.

- Office for National Statistics. (2018). *Families and the labour market, england: 2018. How the employment of men and women aged 16 to 64 years with children has changed over the past two decades and what the current picture looks like*. London: Office for National Statistics.
- Ofsted. (2002). *Changing schools: An evaluation of the effectiveness of transfer arrangements at age 11*. London: Office for Standards in Education.
- Ofsted. (2009). *Family learning: An evaluation of the benefits of family learning for participants, their families and the wider community*. London: Office for Standards in Education.
- Ollendick, T. H., Weist, M. D., Borden, M. C., & Greene, R. W. (1992). Sociometric status and academic, behavioral, and psychological adjustment: A five-year longitudinal study. *Journal of Consulting and Clinical Psychology*, 60(1), 80–87.
<https://doi.org/10.1037//0022-006X.60.1.80>
- Opris, A. M., Cheie, L., Trifan, C. M., & Visu-Petra, L. (2019). Internalising symptoms and verbal working memory in school-age children: A processing efficiency analysis. *International Journal of Psychology*, 54(6), 828–838.
<https://doi.org/10.1002/ijop.12537>
- Owens, M., Stevenson, J., Hadwin, J. A., & Norgate, R. (2012). Anxiety and depression in academic performance: An exploration of the mediating factors of worry and working memory. *School Psychology International*, 33(4), 433–449.
<https://doi.org/10.1177/0143034311427433>

- Owens, M., Stevenson, J., Hadwin, J. A., & Norgate, R. (2014). When does anxiety help or hinder cognitive test performance? The role of working memory capacity. *British Journal of Psychology*, 105(1), 92–101.
<https://doi.org/10.1111/bjop.12009>
- Owens, M., Stevenson, J., Norgate, R., & Hadwin, J. A. (2008). Processing efficiency theory in children: Working memory as a mediator between trait anxiety and academic performance. *Anxiety, Stress, & Coping*, 21(4), 417–430.
<https://doi.org/10.1080/10615800701847823>
- Paget, A., Parker, C., Heron, J., Logan, S., Henley, W., Emond, A., & Ford, T. (2018). Which children and young people are excluded from school? Findings from a large british birth cohort study, the avon longitudinal study of parents and children (alspac). *Child Care, Health and Development*, 44(2), 285–296.
<https://doi.org/10.1111/cch.12525>
- Palmu, I. R., Närhi, V. M., & Savolainen, H. K. (2018). Externalizing behaviour and academic performance—the cross-lagged relationship during school transition. *Emotional and Behavioural Difficulties*, 23(2), 111–126.
<https://doi.org/10.1080/13632752.2017.1376968>
- Park, D., Ramirez, G., & Beilock, S. L. (2014). The role of expressive writing in math anxiety. *Journal of Experimental Psychology: Applied*, 20(2), 103–111.
<https://doi.org/10.1037/xap0000013>
- Parsons, S., & Bynner, J. (1997). Numeracy and employment. *Education + Training*, 39, 43–51. <https://doi.org/10.1108/00400919710164125>

- Passolunghi, M. C., Mammarella, I. C., & Altoè, G. (2008). Cognitive abilities as precursors of the early acquisition of mathematical skills during first through second grades. *Developmental Neuropsychology*, 33(3), 229–250.
<https://doi.org/10.1080/87565640801982320>
- Patalay, P., Deighton, J., Fonagy, P., & Wolpert, M. (2015). The relationship between internalising symptom development and academic attainment in early adolescence. *PloS One*, 10(1), e0116821.
<https://doi.org/10.1371/journal.pone.0116821>
- Pearson, R. M., Bornstein, M. H., Cordero, M., Scerif, G., Mahedy, L., Evans, J., ... Stein, A. (2016). Maternal perinatal mental health and offspring academic achievement at age 16: The mediating role of childhood executive function. *Journal of Child Psychology and Psychiatry*, 57(4), 491–501.
<https://doi.org/10.1111/jcpp.12483>
- Pekrun, R., Lichtenfeld, S., Marsh, H. W., Murayama, K., & Goetz, T. (2017). Achievement emotions and academic performance: Longitudinal models of reciprocal effects. *Child Development*, 88(5), 1653–1670.
<https://doi.org/10.1111/cdev.12704>
- Peterson, J. S., & Ray, K. E. (2006). Bullying and the gifted: Victims, perpetrators, prevalence, and effects. *Gifted Child Quarterly*, 50(2), 148–168.
<https://doi.org/10.1177/001698620605000206>
- Petrides, K. V., Frederickson, N., & Furnham, A. (2004). The role of trait emotional intelligence in academic performance and deviant behavior at school. *Personality*

and Individual Differences, 36(2), 277–293. [https://doi.org/10.1016/S0191-8869\(03\)00084-9](https://doi.org/10.1016/S0191-8869(03)00084-9)

Pinheiro, J., Bates, D., DebRoy, S., Sarkar, D., & R Core Team. (2019). *nlme: Linear and nonlinear mixed effects models*. Retrieved from <https://CRAN.R-project.org/package=nlme>

Pitchforth, J., Fahy, K., Ford, T., Wolpert, M., Viner, R. M., & Hargreaves, D. S. (2019). Mental health and well-being trends among children and young people in the uk, 1995–2014: Analysis of repeated cross-sectional national health surveys. *Psychological Medicine*, 49(8), 1275–1285. <https://doi.org/10.1017/S0033291718001757>

Pitsia, V., Biggart, A., & Karakolidis, A. (2017). The role of students' self-beliefs, motivation and attitudes in predicting mathematics achievement: A multilevel analysis of the programme for international student assessment data. *Learning and Individual Differences*, 55, 163–173. <https://doi.org/10.1016/j.lindif.2017.03.014>

Plomin, R., DeFries, J. C., & Loehlin, J. C. (1977). Genotype-environment interaction and correlation in the analysis of human behavior. *Psychological Bulletin*, 84(2), 309–322. <https://doi.org/10.1037/0033-2909.84.2.309>

Polanczyk, G. V., Salum, G. A., Sugaya, L. S., Caye, A., & Rohde, L. A. (2015). Annual research review: A meta-analysis of the worldwide prevalence of mental disorders in children and adolescents. *Journal of Child Psychology and Psychiatry*, 56(3), 345–365. <https://doi.org/10.1111/jcpp.12381>

- Pophillat, E., Rooney, R. M., Nesa, M., Davis, M. C., Baughman, N., Hassan, S., & Kane, R. T. (2016). Preventing internalizing problems in 6–8 year old children: A universal school-based program. *Frontiers in Psychology*, 7, 1928.
<https://doi.org/10.3389/fpsyg.2016.01928>
- Prandy, K., & Lambert, P. (2003). Marriage, social distance and the social space: An alternative derivation and validation of the cambridge scale. *Sociology*, 37(3), 397–411. <https://doi.org/10.1177/00380385030373001>
- Prince, P., & Gifford, K. (2016). Working memory goes to school. *Applied Neuropsychology: Child*, 5(3), 194–201.
<https://doi.org/10.1080/21622965.2016.1167502>
- Pro Bono Economics. (2014). Pro bono economics report for national numeracy cost of outcomes associated with low levels of adult numeracy in the uk. Retrieved from <https://www.probonoeconomics.com/sites/default/files/files/PBE%20National%20Numeracy%20costs%20report%2011Mar.pdf>
- Qualter, P., Whiteley, H., Hutchinson, J., & Pope, D. (2007). Supporting the development of emotional intelligence competencies to ease the transition from primary to high school. *Educational Psychology in Practice*, 23(1), 79–95.
<https://doi.org/10.1080/02667360601154584>
- Raghubar, K. P., Barnes, M. A., & Hecht, S. A. (2010). Working memory and mathematics: A review of developmental, individual difference, and cognitive approaches. *Learning and Individual Differences*, 20(2), 110–122.
<https://doi.org/10.1016/j.lindif.2009.10.005>

- Rahman, M. A., Todd, C., John, A., Tan, J., Kerr, M., Potter, R., ... Brophy, S. (2018). School achievement as a predictor of depression and self-harm in adolescence: Linked education and health record study. *The British Journal of Psychiatry*, 212(4), 215–221. <https://doi.org/10.1192/bjp.2017.69>
- Raiche, G., & Magis, D. (2020). *Parallel analysis and other non graphical solutions to the cattell scree test*. Retrieved from <https://cran.r-project.org/web/packages/nFactors/nFactors.pdf>
- Ralston, K., Feng, Z., Everington, D., & Dibben, C. (2016). Do young people not in education, employment or training experience long-term occupational scarring? A longitudinal analysis over 20 years of follow-up. *Contemporary Social Science*, 11(2-3), 203–221. <https://doi.org/10.1080/21582041.2016.1194452>
- Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2013). Math anxiety, working memory, and math achievement in early elementary school. *Journal of Cognition and Development*, 14(2), 187–202. <https://doi.org/10.1080/15248372.2012.664593>
- Rapport, M. D., Denney, C. B., Chung, K.-M., & Hustace, K. (2001). Internalizing behavior problems and scholastic achievement in children: Cognitive and behavioral pathways as mediators of outcome. *Journal of Clinical Child Psychology*, 30(4), 536–551. https://doi.org/10.1207/S15374424JCCP3004_10
- Raskauskas, J., & Stoltz, A. D. (2007). Involvement in traditional and electronic bullying among adolescents. *Developmental Psychology*, 43(3), 564–575. <https://doi.org/10.1037/0012-1649.43.3.564>

- Rasmussen, C., & Bisanz, J. (2005). Representation and working memory in early arithmetic. *Journal of Experimental Child Psychology*, 91(2), 137–157.
<https://doi.org/10.1016/j.jecp.2005.01.004>
- Ratelle, C. F., Larose, S., Guay, F., & Senécal, C. (2005). Perceptions of parental involvement and support as predictors of college students' persistence in a science curriculum. *Journal of Family Psychology*, 19(2), 286–293.
<https://doi.org/10.1037/0893-3200.19.2.286>
- R Core Team. (2017). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from <https://www.R-project.org/>
- Reid, R., Gonzalez, J. E., Nordness, P. D., Trout, A., & Epstein, M. H. (2004). A meta-analysis of the academic status of students with emotional/behavioral disturbance. *The Journal of Special Education*, 38(3), 130–143.
<https://doi.org/10.1177/00224669040380030101>
- Reijntjes, A., Kamphuis, J. H., Prinzie, P., & Telch, M. J. (2010). Peer victimization and internalizing problems in children: A meta-analysis of longitudinal studies. *Child Abuse & Neglect*, 34(4), 244–252. <https://doi.org/10.1016/j.chiabu.2009.07.009>
- Rens, M. van, Haelermans, C., Groot, W., & Brink, H. M. van den. (2018). Facilitating a successful transition to secondary school:(How) does it work? A systematic literature review. *Adolescent Research Review*, 3(1), 43–56.
<https://doi.org/10.1007/s40894-017-0063-2>

- Resnick, M. D., Bearman, P. S., Blum, R. W., Bauman, K. E., Harris, K. M., Jones, J., ... others. (1997). Protecting adolescents from harm: Findings from the national longitudinal study on adolescent health. *Jama*, 278(10), 823–832.
<https://doi.org/10.1001/jama.278.10.823>
- Rettew, D. C., & McKee, L. (2005). Temperament and its role in developmental psychopathology. *Harvard Review of Psychiatry*, 13(1), 14–27.
<https://doi.org/10.1080/10673220590923146>
- Revelle, W. (2019). *Psych: Procedures for psychological, psychometric, and personality research*. Evanston, Illinois: Northwestern University. Retrieved from <https://CRAN.R-project.org/package=psych>
- Rice, F., Frederickson, N., & Seymour, J. (2011). Assessing pupil concerns about transition to secondary school. *British Journal of Educational Psychology*, 81(2), 244–263. <https://doi.org/10.1348/000709910X519333>
- Rice, F., Frederickson, N., Shelton, K., McManus, C., Riglin, L., & Ng-Knight, T. (2015). *Identifying factors that predict successful and difficult transitions to secondary school*. London: University College London.
- Rice, J. K. (2001). Explaining the negative impact of the transition from middle to high school on student performance in mathematics and science. *Educational Administration Quarterly*, 37(3), 372–400.
<https://doi.org/10.1177/00131610121969352>

- Richardson, F. C., & Suinn, R. M. (1972). The mathematics anxiety rating scale: Psychometric data. *Journal of Counseling Psychology*, 19(6), 551–554.
<https://doi.org/10.1037/h0033456>
- Riglin, L., Frederickson, N., Shelton, K. H., & Rice, F. (2013). A longitudinal study of psychological functioning and academic attainment at the transition to secondary school. *Journal of Adolescence*, 36(3), 507–517.
<https://doi.org/10.1016/j.adolescence.2013.03.002>
- Riglin, L., Petrides, K., Frederickson, N., & Rice, F. (2014). The relationship between emotional problems and subsequent school attainment: A meta-analysis. *Journal of Adolescence*, 37(4), 335–346.
<https://doi.org/10.1016/j.adolescence.2014.02.010>
- Rimfeld, K., Kovas, Y., Dale, P. S., & Plomin, R. (2015). Pleiotropy across academic subjects at the end of compulsory education. *Scientific Reports*, 5, 11713.
<https://doi.org/10.1038/srep11713>
- Ritchie, S. J., & Bates, T. C. (2013). Enduring links from childhood mathematics and reading achievement to adult socioeconomic status. *Psychological Science*, 24(7), 1301–1308. <https://doi.org/10.1177/0956797612466268>
- Robbers, E., Donche, V., De Maeyer, S., & Van Petegem, P. (2018). A longitudinal study of learning conceptions on the transition between primary and secondary education. *Research Papers in Education*, 33(3), 375–392.
<https://doi.org/10.1080/02671522.2017.1329337>

Roeser, R. W., Eccles, J. S., & Sameroff, A. J. (2000). School as a context of early adolescents' academic and social-emotional development: A summary of research findings. *The Elementary School Journal*, 100(5), 443–471.

<https://doi.org/10.1086/499650>

Ronalds, G. A., De Stavola, B. L., & Leon, D. A. (2005). The cognitive cost of being a twin: Evidence from comparisons within families in the aberdeen children of the 1950s cohort study. *Bmj*, 331(7528), 1306.

<https://doi.org/10.1136/bmj.38633.594387.3A>

Rose, A. J., & Rudolph, K. D. (2006). A review of sex differences in peer relationship processes: Potential trade-offs for the emotional and behavioral development of girls and boys. *Psychological Bulletin*, 132(1), 98–131.

<https://doi.org/10.1037/0033-2909.132.1.98>

Rosenblatt, J. L., & Elias, M. J. (2008). Dosage effects of a preventive social-emotional learning intervention on achievement loss associated with middle school transition. *The Journal of Primary Prevention*, 29(6), 535–555.

<https://doi.org/10.1007/s10935-008-0153-9>

Ross, E. J., Graham, D. L., Money, K. M., & Stanwood, G. D. (2015). Developmental consequences of fetal exposure to drugs: What we know and what we still must learn. *Neuropsychopharmacology*, 40(1), 61–87.

<https://doi.org/10.1038/npp.2014.147>

- Rosseel, Y. (2012). lavaan: An R package for structural equation modeling. *Journal of Statistical Software*, 48(2), 1–36. Retrieved from <http://www.jstatsoft.org/v48/i02/>
- Rudolph, K. D., Lambert, S. F., Clark, A. G., & Kurlakowsky, K. D. (2001). Negotiating the transition to middle school: The role of self-regulatory processes. *Child Development*, 72(3), 929–946. <https://doi.org/10.1111/1467-8624.00325>
- Russo, J., Bobis, J., Sullivan, P., Downton, A., Livy, S., McCormick, M., & Hughes, S. (2020). Exploring the relationship between teacher enjoyment of mathematics, their attitudes towards student struggle and instructional time amongst early years primary teachers. *Teaching and Teacher Education*, 88, 102983. <https://doi.org/10.1016/j.tate.2019.102983>
- Sabates, R., Duckworth, K., & Feinstein, L. (2011). The impact of mothers' adult learning on their children's academic performance at key stage 3: Evidence from alspac. *Oxford Review of Education*, 37(4), 485–504. <https://doi.org/10.1080/03054985.2011.601102>
- Sasanguie, D., Van den Bussche, E., & Reynvoet, B. (2012). Predictors for mathematics achievement? Evidence from a longitudinal study. *Mind, Brain, and Education*, 6(3), 119–128. <https://doi.org/10.1111/j.1751-228X.2012.01147.x>
- Sawyer, M. G., Arney, F. M., Baghurst, P. A., Clark, J. J., Graetz, B. W., Kosky, R. J., ... others. (2001). The mental health of young people in australia: Key findings from the child and adolescent component of the national survey of mental health

and well-being. *Australian & New Zealand Journal of Psychiatry*, 35(6), 806–814. <https://doi.org/10.1046/j.1440-1614.2001.00964.x>

Scarr, S., & McCartney, K. (1983). How people make their own environments: A theory of genotype→ environment effects. *Child Development*, 54(2), 424–435. <https://doi.org/10.2307/1129703>

Schaffhuser, K., Allemand, M., & Schwarz, B. (2017). The development of self-representations during the transition to early adolescence: The role of gender, puberty, and school transition. *The Journal of Early Adolescence*, 37(6), 774–804. <https://doi.org/10.1177/0272431615624841>

Schenke, K., Lam, A. C., Conley, A. M., & Karabenick, S. A. (2015). Adolescents' help seeking in mathematics classrooms: Relations between achievement and perceived classroom environmental influences over one school year. *Contemporary Educational Psychology*, 41, 133–146. <https://doi.org/10.1016/j.cedpsych.2015.01.003>

Schneider, S., Houweling, J. E., Gommlich-Schneider, S., Klein, C., Nündel, B., & Wolke, D. (2009). Effect of maternal panic disorder on mother–child interaction and relation to child anxiety and child self-efficacy. *Archives of Women's Mental Health*, 12(4), 251–259. <https://doi.org/10.1007/s00737-009-0072-7>

Schulenberg, J. E., Asp, C. E., & Petersen, A. C. (1984). School from the young adolescent's perspective: A descriptive report. *The Journal of Early Adolescence*, 4(2), 107–130. <https://doi.org/10.1177/0272431684042002>

- Schwartz, D., Gorman, A. H., Nakamoto, J., & McKay, T. (2006). Popularity, social acceptance, and aggression in adolescent peer groups: Links with academic performance and school attendance. *Developmental Psychology*, 42(6), 1116–1127. <https://doi.org/10.1037/0012-1649.42.6.1116>
- See, B. H., Morris, R., Gorard, S., & Siddiqui, N. (2019). Evaluation of the impact of maths counts delivered by teaching assistants on primary school pupils' attainment in maths. *Educational Research and Evaluation*, 25(3-4), 203–224. <https://doi.org/10.1080/13803611.2019.1686031>
- Seidman, E., Allen, L., Aber, J. L., Mitchell, C., & Feinman, J. (1994). The impact of school transitions in early adolescence on the self-system and perceived social context of poor urban youth. *Child Development*, 65(2), 507–522. <https://doi.org/10.2307/1131399>
- Seidman, E., Lambert, L. E., Allen, L., & Aber, J. L. (2003). Urban adolescents' transition to junior high school and protective family transactions. *The Journal of Early Adolescence*, 23(2), 166–193. <https://doi.org/10.1177/0272431603023002003>
- Seipp, B. (1991). Anxiety and academic performance: A meta-analysis of findings. *Anxiety Research*, 4(1), 27–41. <https://doi.org/10.1080/08917779108248762>
- Serbin, L. A., Stack, D. M., & Kingdon, D. (2013). Academic success across the transition from primary to secondary schooling among lower-income adolescents: Understanding the effects of family resources and gender. *Journal*

of Youth and Adolescence, 42(9), 1331–1347. <https://doi.org/10.1007/s10964-013-9987-4>

Shakeshaft, N. G., Trzaskowski, M., McMillan, A., Rimfeld, K., Krapohl, E., Haworth, C. M., ... Plomin, R. (2013). Strong genetic influence on a uk nationwide test of educational achievement at the end of compulsory education at age 16. *PloS One*, 8(12), e80341. <https://doi.org/10.1371/journal.pone.0080341>

Shalev, R. S. (2004). Developmental dyscalculia. *Journal of Child Neurology*, 19(10), 765–771. <https://doi.org/10.1177/08830738040190100601>

Shell, M. D., Gazelle, H., & Faldowski, R. A. (2014). Anxious solitude and the middle school transition: A diathesis × stress model of peer exclusion and victimization trajectories. *Developmental Psychology*, 50(5), 1569–1583. <https://doi.org/10.1037/a0035528>

Shepherd, J., & Roker, D. (2005). *An evaluation of a 'transition to secondary school' project run by the national pyramid trust*. Brighton: Trust for the Study of Adolescence.

Sher-Censor, E., Parke, R. D., & Coltrane, S. (2011). Parents' promotion of psychological autonomy, psychological control, and mexican–american adolescents' adjustment. *Journal of Youth and Adolescence*, 40(5), 620–632. <https://doi.org/10.1007/s10964-010-9552-3>

Siddiqui, N., Gorard, S., & See, B. H. (2014). Is a summer school programme a promising intervention in preparation for transition from primary to secondary

school? *International Education Studies*, 7(7), 125–135.

<https://doi.org/10.5539/ies.v7n7p125>

Siddiqui, N., Gorard, S., & See, B. H. (2016). Accelerated reader as a literacy catch-up intervention during primary to secondary school transition phase. *Educational Review*, 68(2), 139–154. <https://doi.org/10.1080/00131911.2015.1067883>

Simmons, R. G., Black, A., & Zhou, Y. (1991). African–american versus white children and the transition into junior high school. *American Journal of Education*, 99(4), 481–520. <https://doi.org/10.1086/443995>

Skaalvik, E. M., Federici, R. A., Wigfield, A., & Tangen, T. N. (2017). Students’ perceptions of mathematics classroom goal structures: Implications for perceived task values and study behavior. *Social Psychology of Education*, 20(3), 543–563. <https://doi.org/10.1007/s11218-017-9382-1>

Skinner, E. A., Zimmer-Gembeck, M. J., Connell, J. P., Eccles, J. S., & Wellborn, J. G. (1998). Individual differences and the development of perceived control. *Monographs of the Society for Research in Child Development*, 63(2–3), i–231. <https://doi.org/10.2307/1166220>

Skwarchuk, S.-L., Sowinski, C., & LeFevre, J.-A. (2014). Formal and informal home learning activities in relation to children’s early numeracy and literacy skills: The development of a home numeracy model. *Journal of Experimental Child Psychology*, 121, 63–84. <https://doi.org/10.1016/j.jecp.2013.11.006>

Smedsrud, J., Nordahl-Hansen, A., Idsøe, E. M., Ulvund, S. E., Idsøe, T., & Lang-Ree, O. C. (2019). The associations between math achievement and perceived

relationships in school among high intelligent versus average adolescents.

Scandinavian Journal of Educational Research, 63(7), 1041–1055.

<https://doi.org/10.1080/00313831.2018.1476406>

Smith, G., Sylva, K., Smith, T., Sammons, P., & Omonigho, A. (2018). *Stop start: Survival, decline or closure? Children's centres in england, 2018*. London: Sutton Trust.

Smyth, E. (2016). Social relationships and the transition to secondary education. *The Economic and Social Review*, 47(4), 451–476.

Spitzer, R. L., Kroenke, K., Williams, J. B., & Löwe, B. (2006). A brief measure for assessing generalized anxiety disorder: The gad-7. *Archives of Internal Medicine*, 166(10), 1092–1097. <https://doi.org/10.1001/archinte.166.10.1092>

St Clair-Thompson, H. L., & Gathercole, S. E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *Quarterly Journal of Experimental Psychology*, 59(4), 745–759. <https://doi.org/10.1080/17470210500162854>

Steele, R. G., Armistead, L., & Forehand, R. (2000). Concurrent and longitudinal correlates of depressive symptoms among low-income, urban, african american children. *Journal of Clinical Child Psychology*, 29(1), 76–85. https://doi.org/10.1207/S15374424jccp2901_8

Stone, L. L., Otten, R., Engels, R. C., Vermulst, A. A., & Janssens, J. M. (2010). Psychometric properties of the parent and teacher versions of the strengths and difficulties questionnaire for 4-to 12-year-olds: A review. *Clinical Child and*

Family Psychology Review, 13(3), 254–274. <https://doi.org/10.1007/s10567-010-0071-2>

Strauss, E., Sherman, E. M. S., & Spreen, O. A. (2006). *A compendium of neuropsychological tests*. Oxford: Oxford University Press.

Suárez-Pellicioni, M., Núñez-Peña, M. I., & Colomé, À. (2016). Math anxiety: A review of its cognitive consequences, psychophysiological correlates, and brain bases. *Cognitive, Affective, & Behavioral Neuroscience*, 16(1), 3–22. <https://doi.org/10.3758/s13415-015-0370-7>

Suntheimer, N. M., & Wolf, S. (2020). Cumulative risk, teacher-child closeness, executive function and early academic skills in kindergarten children. *Journal of School Psychology*, 78, 23–37. <https://doi.org/10.1016/j.jsp.2019.11.005>

Swars, S. L., Daane, C., & Giesen, J. (2006). Mathematics anxiety and mathematics teacher efficacy: What is the relationship in elementary preservice teachers? *School Science and Mathematics*, 106(7), 306–315. <https://doi.org/10.1111/j.1949-8594.2006.tb17921.x>

Tandon, M., Cardeli, E., & Luby, J. (2009). Internalizing disorders in early childhood: A review of depressive and anxiety disorders. *Child and Adolescent Psychiatric Clinics*, 18(3), 593–610. <https://doi.org/10.1016/j.chc.2009.03.004>

Teng, Y. (2019). The relationship between school climate and students' mathematics achievement gaps in shanghai china: Evidence from pisa 2012. *Asia Pacific Journal of Education*, 1–17. <https://doi.org/10.1080/02188791.2019.1682516>

- Thapa, A., Cohen, J., Guffey, S., & Higgins-D'Alessandro, A. (2013). A review of school climate research. *Review of Educational Research*, 83(3), 357–385.
<https://doi.org/10.3102/0034654313483907>
- Thomson, M. M., Walkowiak, T. A., Whitehead, A. N., & Huggins, E. (2020). Mathematics teaching efficacy and developmental trajectories: A mixed-methods investigation of novice k-5 teachers. *Teaching and Teacher Education*, 87, 102953. <https://doi.org/10.1016/j.tate.2019.102953>
- Thornburg, H. D., & Glider, P. (1984). Dimensions of early adolescent social perceptions and preferences. *The Journal of Early Adolescence*, 4(4), 387–406.
<https://doi.org/10.1177/0272431684044008>
- Tram, J. M., & Cole, D. A. (2006). A multimethod examination of the stability of depressive symptoms in childhood and adolescence. *Journal of Abnormal Psychology*, 115(4), 674. <https://doi.org/10.1037/0021-843X.115.4.674>
- Twenge, J. M., Joiner, T. E., Rogers, M. L., & Martin, G. N. (2018). Increases in depressive symptoms, suicide-related outcomes, and suicide rates among us adolescents after 2010 and links to increased new media screen time. *Clinical Psychological Science*, 6(1), 3–17. <https://doi.org/10.1177/2167702617723376>
- UNESCO Institute for Statistics. (2010). *Global education digest 2010: Comparing education statistics across the world*. Montreal, Canada: UNESCO Institute for Statistics.

- Van Ameringen, M., Mancini, C., & Farvolden, P. (2003). The impact of anxiety disorders on educational achievement. *Journal of Anxiety Disorders*, 17(5), 561–571. [https://doi.org/10.1016/S0887-6185\(02\)00228-1](https://doi.org/10.1016/S0887-6185(02)00228-1)
- van Buuren, S., & Groothuis-Oudshoorn, K. (2011). mice: Multivariate imputation by chained equations in r. *Journal of Statistical Software*, 45(3), 1–67. Retrieved from <https://www.jstatsoft.org/v45/i03/>
- Van de Weijer-Bergsma, E., Kroesbergen, E. H., & Van Luit, J. E. (2015). Verbal and visual-spatial working memory and mathematical ability in different domains throughout primary school. *Memory & Cognition*, 43(3), 367–378. <https://doi.org/10.3758/s13421-014-0480-4>
- Van Petegem, K., Aelterman, A., Van Keer, H., & Rosseel, Y. (2008). The influence of student characteristics and interpersonal teacher behaviour in the classroom on student's wellbeing. *Social Indicators Research*, 85(2), 279–291. <https://doi.org/10.1007/s11205-007-9093-7>
- Vaz, S., Falkmer, M., Parsons, R., Passmore, A. E., Parkin, T., & Falkmer, T. (2014). School belongingness and mental health functioning across the primary-secondary transition in a mainstream sample: Multi-group cross-lagged analyses. *PLoS One*, 9(6), e99576. <https://doi.org/10.1371/journal.pone.0099576>
- Vaz, S., Parsons, R., Falkmer, T., Passmore, A. E., & Falkmer, M. (2014). The impact of personal background and school contextual factors on academic competence and mental health functioning across the primary-secondary school transition. *PloS One*, 9(3), e89874. <https://doi.org/10.1371/journal.pone.0089874>

- Visu-Petra, L., Cheie, L., Benga, O., & Packiam Alloway, T. (2011). Effects of anxiety on memory storage and updating in young children. *International Journal of Behavioral Development*, 35(1), 38–47.
<https://doi.org/10.1177/0165025410368945>
- Visu-Petra, L., Miclea, M., Cheie, L., & Benga, O. (2009). Processing efficiency in preschoolers' memory span: Individual differences related to age and anxiety. *Journal of Experimental Child Psychology*, 103(1), 30–48.
<https://doi.org/10.1016/j.jecp.2008.09.002>
- Vukovic, R. K., Roberts, S. O., & Green Wright, L. (2013). From parental involvement to children's mathematical performance: The role of mathematics anxiety. *Early Education & Development*, 24(4), 446–467.
<https://doi.org/10.1080/10409289.2012.693430>
- Wang, J., Hu, S., & Wang, L. (2018). Multilevel analysis of personality, family, and classroom influences on emotional and behavioral problems among chinese adolescent students. *PLoS One*, 13(8), e0201442.
<https://doi.org/10.1371/journal.pone.0201442>
- Wang, M.-T., Brinkworth, M., & Eccles, J. (2013). Moderating effects of teacher–student relationship in adolescent trajectories of emotional and behavioral adjustment. *Developmental Psychology*, 49(4), 690–705.
<https://doi.org/10.1037/a0027916>
- Wang, M.-T., & Degol, J. L. (2017). Gender gap in science, technology, engineering, and mathematics (stem): Current knowledge, implications for practice, policy,

and future directions. *Educational Psychology Review*, 29(1), 119–140.

<https://doi.org/10.1007/s10648-015-9355-x>

Wang, W., Brittain, H., McDougall, P., & Vaillancourt, T. (2016). Bullying and school transition: Context or development? *Child Abuse & Neglect*, 51, 237–248.

<https://doi.org/10.1016/j.chiabu.2015.10.004>

Wang, Z., Hart, S. A., Kovas, Y., Lukowski, S., Soden, B., Thompson, L. A., ... others. (2014). Who is afraid of math? Two sources of genetic variance for mathematical anxiety. *Journal of Child Psychology and Psychiatry*, 55(9), 1056–1064. <https://doi.org/10.1111/jcpp.12224>

Warnes, G. R., Bolker, B., Lumley, T., Randall C. Johnson are Copyright SAIC-Frederick, R. C. J. C. from, Intramural Research Program, I. F. by the, NIH, ... Cancer Research under NCI Contract NO1-CO-12400, C. for. (2018). *Gmodels: Various r programming tools for model fitting*. Retrieved from <https://CRAN.R-project.org/package=gmodels>

Waszczuk, M. A., Brown, H. M., Eley, T. C., & Lester, K. J. (2015). Attentional control theory in childhood: Enhanced attentional capture by non-emotional and emotional distractors in anxiety and depression. *PloS One*, 10(11), e0141535.

<https://doi.org/10.1371/journal.pone.0141535>

Waters, S., Lester, L., & Cross, D. (2014). How does support from peers compare with support from adults as students transition to secondary school? *Journal of Adolescent Health*, 54(5), 543–549.

<https://doi.org/10.1016/j.jadohealth.2013.10.012>

- Wechsler, D. (1991). *Manual for the Wechsler Intelligence Scale for Children-Third Edition*. San Antonio: TX: The Psychological Corporation.
- Wehby, G. L., Prater, K., McCarthy, A. M., Castilla, E. E., & Murray, J. C. (2011). The impact of maternal smoking during pregnancy on early child neurodevelopment. *Journal of Human Capital*, 5(2), 207–254. <https://doi.org/10.1086/660885>
- West, P., Sweeting, H., & Young, R. (2010). Transition matters: Pupils' experiences of the primary–secondary school transition in the west of Scotland and consequences for well-being and attainment. *Research Papers in Education*, 25(1), 21–50. <https://doi.org/10.1080/02671520802308677>
- White, I. R., Royston, P., & Wood, A. M. (2011). Multiple imputation using chained equations: Issues and guidance for practice. *Statistics in Medicine*, 30(4), 377–399. <https://doi.org/10.1002/sim.4067>
- Wickham, H. (2017). *Tidyverse: Easily install and load the 'tidyverse'*. Retrieved from <https://CRAN.R-project.org/package=tidyverse>
- Wigfield, A., Eccles, J. S., Mac Iver, D., Reuman, D. A., & Midgley, C. (1991). Transitions during early adolescence: Changes in children's domain-specific self-perceptions and general self-esteem across the transition to junior high school. *Developmental Psychology*, 27(4), 552–565. <https://doi.org/10.1037/0012-1649.27.4.552>
- Wilkins, J. L., & Ma, X. (2003). Modeling change in student attitude toward and beliefs about mathematics. *The Journal of Educational Research*, 97(1), 52–63. <https://doi.org/10.1080/00220670309596628>

- Wolke, D., Lereya, S., Fisher, H., Lewis, G., & Zammit, S. (2014). Bullying in elementary school and psychotic experiences at 18 years: A longitudinal, population-based cohort study. *Psychological Medicine*, 44(10), 2199–2211. <https://doi.org/10.1017/S0033291713002912>
- Wolke, D., Rios, P., & Unzer, A. (1995). AMCIES evaluation of mother-child interaction with the etch-a-sketch. *Unpublished Manuscript, University of Hertfordshire*.
- Woodward, L. J., & Fergusson, D. M. (2000). Childhood peer relationship problems and later risks of educational under-achievement and unemployment. *The Journal of Child Psychology and Psychiatry and Allied Disciplines*, 41(2), 191–201.
- Wright, H., Dorsett, R., Anders, J., Buzzeo, J., Runge, J., & Sanders, M. (2019). *Improving working memory. Evaluation report*. London: The Education Endowment Foundation.
- Wu, S., Amin, H., Barth, M., Malcarne, V., & Menon, V. (2012). Math anxiety in second and third graders and its relation to mathematics achievement. *Frontiers in Psychology*, 3, 162. <https://doi.org/10.3389/fpsyg.2012.00162>
- Wu, S. S., Willcutt, E. G., Escovar, E., & Menon, V. (2014). Mathematics achievement and anxiety and their relation to internalizing and externalizing behaviors. *Journal of Learning Disabilities*, 47(6), 503–514. <https://doi.org/10.1177/0022219412473154>

Xuan, X., Xue, Y., Zhang, C., Luo, Y., Jiang, W., Qi, M., & Wang, Y. (2019).

Relationship among school socioeconomic status, teacher-student relationship, and middle school students' academic achievement in china: Using the multilevel mediation model. *PloS One*, *14*(3), e0213783.

<https://doi.org/10.1371/journal.pone.0213783>

Zandstra, A. R. E., Ormel, J., Nederhof, E., Hoekstra, P. J., & Hartman, C. A. (2015).

The role of basal cortisol in predicting change in mental health problems across the transition to middle school. *Journal of Adolescent Health*, *56*(5), 489–495.

<https://doi.org/10.1016/j.jadohealth.2014.12.004>

Zeedyk, M. S., Gallacher, J., Henderson, M., Hope, G., Husband, B., & Lindsay, K.

(2003). Negotiating the transition from primary to secondary school: Perceptions of pupils, parents and teachers. *School Psychology International*, *24*(1), 67–79.

<https://doi.org/10.1177/0143034303024001010>

Zimmerman, B. J., & Martinez-Pons, M. (1990). Student differences in self-regulated

learning: Relating grade, sex, and giftedness to self-efficacy and strategy use.

Journal of Educational Psychology, *82*(1), 51–59. [https://doi.org/10.1037/0022-](https://doi.org/10.1037/0022-0663.82.1.51)

[0663.82.1.51](https://doi.org/10.1037/0022-0663.82.1.51)

Appendix

Table 20.

Individual items forming the composite measures in the primary education model.

| Composite measure | Items |
|-------------------|--|
| School affect | My school was a place where other pupils accepted me as I am My school was a place where I felt lonely My school was a place where I felt worried My school was a place where I people trusted me My school was a place where I knew people thought a lot of me My school was a place where I got on well with the other pupils in my class My school was a place where other pupils were very friendly My school was a place where I felt restless |
| S-T relationships | My school was a place where I felt proud to be a pupil My school was a place where my teacher listens to what I say My school was a place where my teacher treated me fairly in class |
| Maths attitudes | I hate mathematics Maths is easy for me I look forward to mathematics I get good marks in maths I am interested in maths I learn things quickly in maths I like maths I'm good at maths I enjoy doing work in maths I am bad at maths |
| Teacher affect | I really enjoy teaching I would prefer to get out of teaching I like the challenge of making children understand I really enjoy teaching numeracy skills Changes in the curriculum are an exciting challenge Being a teacher is really worthwhile |

Table 21.

Individual items forming the composite measures in the secondary education model.

| Composite measure | Items |
|-------------------------|--|
| School belonging | My school is a place where other pupils accept me as I am My school is a place where I feel proud to be a pupil My school is a place where people trust me My school is a place where I know people think a lot of me My school is a place where I get on well with other pupils in my classes My school is a place where other pupils are very friendly |
| S-T relationships | Most of my teachers don't really listen to what I say in class I get treated unfairly by most of my teachers |
| Negative school emotion | My school is a place where I feel lonely My school is a place where I feel worried My school is a place where I feel restless |
| Maths attitudes | How much do you like doing maths? In general, how useful is what you learn in maths? For me, being good in these subjects (maths) is (important) |
| Positive teaching | My maths teacher tries to make maths interesting My maths teacher likes maths My maths teacher understands maths really well My maths teacher can explain things to me when I don't understand them My maths teacher has helped me learn things in maths that I thought I couldn't understand Everyone is encouraged to do their very best My maths teacher cares about how we feel about life in general My maths teacher is friendly to us My maths teacher criticises all of us equally if we do poor work My maths teacher gives us time to really explore and understand new things In our class, trying hard is very important |
| Teacher fairness | My maths teacher only cares about the clever students My maths teacher has given up on some of the students in the class My maths teacher thinks that some of the students in this class can't do very good work My maths teacher treats boys and girls differently My maths teacher treats some students better than other students |